Journal

of

THE ROYAL AERONAUTICAL SOCIETY

IN WHICH ARE INCORPORATED THE INSTITUTION OF AERONAUTICAL ENGINEERS
AND THE HELICOPTER ASSOCIATION OF GREAT BRITAIN

A Monthly Illustrated Journal devoted to all subjects connected with the Profession of Aeronautics

EDITED FOR THE COUNCIL OF THE
ROYAL AERONAUTICAL SOCIETY

by

JOAN BRADBROOKE, Associate

Volume LXIV January - December 1960

PRINTED BY THE LEWES PRESS, WIGHTMAN & CO. LTD., LEWES, SUSSEX, ENGLAND, AND PUBLISHED
BY THE ROYAL AERONAUTICAL SOCIETY, 4 HAMILTON PLACE, LONDON, W.1, ENGLAND

XUM

THE UNIVERSITY
OF MICHIGAN
MAR 1 1960
ENGINEERING
LIBRARY

Journal

of

THE ROYAL AERONAUTICAL SOCIETY

JANUARY 1960

CONTENTS

NOTICES

SOME RECENT PROGRESS IN AIR SURVEY WITH PARTICULAR REFERENCE TO NEWLY-DEVELOPED TERRITORIES—THE FIFTEENTH BRITISH COMMONWEALTH LECTURE — W. P. SMITH

THE IMPERIAL COLLEGE HYPERSONIC GUN TUNNEL; AUGUST 1958-JULY 1959 — J. L. STOLLERY, D. J. MAULL AND B. J. BELCHER

TECHNICAL NOTES

A Controlled Experiment on the Subjective Effects of Jet Engine Noise—W. C. T. COPELAND, I. M. DAVIDSON, T. J. HARGEST and D. W. ROBINSON. On Similar Solutions of the Boundary Layer Equations for Air in Dissociation Equilibrium—R. L. DOMMETT. A Closed Formula for the Drag of a Flat Plate with Transition in the Absence of a Pressure Gradient—A. R. COLLAR. Safety in Relation to Structural Failure—Comment by A. H. CRAWSHAW and Reply by A. E. RUSSELL.

GRADUATES' AND STUDENTS' SECTION

THE BRANCHES

THE SEVENTH ANGLO-AMERICAN AERONAUTICAL CONFERENCE, NEW YORK, 1959

THE LIBRARY — REVIEWS — REPORTS

TWELVE SHILLINGS AND SIXPENCE MONTHLY

LONDON

4 HAMILTON PLACE W1

High Performance with Texas Transistors

Smiths 100,000 ft Altimeter

The Smiths 100,000 ft Altimeter introduces a radically new design which gives greatly increased sensitivity and accuracy. The conventional mechanical linkage from pressure sensitive element to presentation gearing is replaced by an electro-magnetic pick-off and external amplifier which supplies power to a servomotor in the altimeter. Transistorisation of the amplifier with Texas Silicon Transistors cuts the weight by 3 lb and the bulk size by 80 per cent, and at the same time gives the equipment greater ruggedness. The transistors are from the Texas small signal range 2S002-5 and 2S014. Whatever your problem there is a wide range of Texas transistors, silicon rectifiers, and other semiconductor devices to give you high performance in all your needs.

STOP PRESS! **GERMANIUM POWER TRANSISTORS**
Available Now Ex Stock 5A 60V PHONE US FOR DETAILS

TEXAS INSTRUMENTS LIMITED

TELEPHONE: BEDFORD 68051 DALLAS ROAD, BEDFORD CABLES: TEXINLIM, BEDFORD

T39/2

Journal of

THE ROYAL AERONAUTICAL SOCIETY

WITH WHICH IS INCORPORATED THE INSTITUTION OF AERONAUTICAL ENGINEERS

PUBLISHED MONTHLY AT

4 HAMILTON PLACE, LONDON, W.1

Telephone: Grosvenor 3515-9 *Telegrams:* Didaskalos, Audley, London

SUBSCRIPTIONS: £7 10s. 0d. PER ANNUM, PLUS 9s. POSTAGE AND PACKING
SINGLE COPIES: 12s. 6d. PLUS 9d. POSTAGE AND PACKING

VOLUME 64 JANUARY 1960 NUMBER 589

CONTENTS

PAGE

Notices 1

The New Year—The Rotorcraft Section—£5,000 Prize for First Successful Man Powered Aircraft Flight—Fifth Air Transport Course, 1960—Branches Conference 1960—Honours Awarded to Members—President of the Institute of the Aeronautical Sciences—Diary—Annual Subscriptions—Past-Presidents of the Society—Discussion on Soviet Control Engineering Progress—Civil Aircraft Accident Investigation Procedure—Sir Henry Tizard—The Exploration of Space—Elections—News of Members—Summaries of Lectures.

Some Recent Progress in Air Survey with Particular Reference to Newly-Developed Territories—The Fifteenth British Commonwealth Lecture — W. P. SMITH — 1

The Imperial College Hypersonic Gun Tunnel; August 1958–July 1959 — J. L. STOLLERY, D. J. MAULL and B. J. BELCHER — 24

Technical Notes 33

A Controlled Experiment on the Subjective Effects of Jet Engine Noise—W. C. T. COPELAND, I. M. DAVIDSON, T. J. HARGEST and D. W. ROBINSON. On Similar Solutions of the Boundary Layer Equations for Air in Dissociation Equilibrium—R. L. DOMMETT. A Closed Formula for the Drag of a Flat Plate with Transition in the Absence of a Pressure Gradient—A. R. COLLAR. Safety in Relation to Structural Failure—Comment by A. H. CRAWSHAW and Reply by A. E. RUSSELL.

Graduates' and Students' Section 41

Branches Pages 42

The Seventh Anglo-American Aeronautical Conference, New York, 1959 44

The Library 52

REVIEWS: Metal Fatigue—Jane's All The World's Aircraft, 1959-60—Medical Aspects of Flight Safety—Air Aces of the 1914-1918 War—Fundamentals of Radio Telemetry—Die Alten Adler.

ADDITIONS TO THE LIBRARY. REPORTS.

All communications for publication in the JOURNAL *should be addressed to the Editor,* JOAN BRADBROOKE, *A.R.Ae.S.; all communications on general matters affecting the Society should be addressed to the Secretary,* A. M. BALLANTYNE, *T.D., B.Sc., Ph.D., F.R.Ae.S., Hon.F.C.A.I., F.I.A.S.*

None of the papers or paragraphs must be taken as expressing the opinion of the Council of the Royal Aeronautical Society unless otherwise stated.

ADVERTISEMENT OFFICE: *One Arundel Street, Strand, London, W.C.2 Covent Garden* 1612.

PRINTED BY THE LEWES PRESS, WIGHTMAN & CO. LTD., LEWES, SUSSEX, ENGLAND, AND PUBLISHED BY THE ROYAL AERONAUTICAL SOCIETY, 4 HAMILTON PLACE, LONDON, W.1, ENGLAND

The Royal Aeronautical Society

(Founded 1866)

PATRON
HER MAJESTY THE QUEEN

COUNCIL 1959—1960

PRESIDENT
PETER G. MASEFIELD, M.A., F.R.Ae.S., Hon.F.I.A.S., M.Inst.T.

PAST-PRESIDENTS
E. T. JONES, C.B., O.B.E., M.Eng., F.R.Ae.S., Hon.F.I.A.S.
SIR GEORGE EDWARDS, C.B.E., B.Sc., F.R.Ae.S., Hon.F.I.A.S.
SIR ARNOLD HALL, M.A., F.R.S., F.R.Ae.S.

PRESIDENT-ELECT
DR. E. S. MOULT, C.B.E., B.Sc.(Eng.), F.R.Ae.S., M.I.Mech.E.

VICE-PRESIDENTS
AIR MARSHAL SIR OWEN JONES, K.B.E., C.B., A.F.C., B.A., D.I.C., F.R.Ae.S., M.I.Mech.E.
AIR COMMODORE F. R. BANKS, C.B., O.B.E., C.G.I.A., F.R.Ae.S. Hon.F.I.A.S., M.I.Mech.E.
PROFESSOR A. R. COLLAR, M.A., D.Sc., F.R.Ae.S., F.I.A.S.

ORDINARY MEMBERS

A. D. BAXTER, M.Eng., F.R.Ae.S., M.I.Mech.E.
MAJOR G. P. BULMAN, C.B.E., B.Sc., F.R.Ae.S.
SIR SYDNEY CAMM, C.B.E., F.R.Ae.S.
DR. W. CAWOOD, C.B., C.B.E., B.Sc., F.R.Ae.S.
J. R. COWNIE, B.Sc.(Eng.), Grad.R.Ae.S.
SIR WILLIAM S. FARREN, C.B., M.B.E., M.A., D.Sc., F.R.S., Hon.F.R.Ae.S., Hon.F.I.A.S., M.I.Mech.E.
L. G. FRISE, B.Sc., F.R.Ae.S., A.F.I.A.S.
SIR GEORGE GARDNER, K.B.E., C.B., D.Sc., F.R.Ae.S., M.I.Mech.E.
H. H. GARDNER, B.Sc., F.R.Ae.S.
SIR HARRY M. GARNER, K.B.E., C.B., M.A., F.R.Ae.S.
D. KEITH-LUCAS, M.A., F.R.Ae.S., M.I.Mech.E.
M. B. MORGAN, C.B., M.A., F.R.Ae.S.
SQUADRON LEADER R. C. G. T. ROGERS, D.C.Ae., A.F.R.Ae.S., R.A.F.
A. A. RUBBRA, B.Sc., F.R.Ae.S., M.I.Mech.E.
B. S. SHENSTONE, M.A.Sc., F.R.Ae.S., F.C.A.I., A.F.I.A.S.
W. TYE, O.B.E., B.Sc., F.R.Ae.S.
T. A. WOLSTENHOLME, A.R.Ae.S.

OFFICERS

Hon. Treasurer: MAJOR G. P. BULMAN, C.B.E., B.Sc., F.R.Ae.S.
Solicitor: L. A. WINGFIELD, M.C., D.F.C., A.R.Ae.S.
Secretary: A. M. BALLANTYNE, T.D., B.Sc.(Eng.), Ph.D., F.R.Ae.S., Hon. F.C.A.I., F.I.A.S.

January 1960

NOTICES

The New Year

The President, Council and Staff of the Society send greetings and good wishes to all members of the Society at home and overseas.

£5,000 Prize for First Successful Man Powered Aircraft Flight

A prize of £5,000 has most generously been offered by Mr. Henry Kremer for the first successful flight of a Man Powered Aircraft designed, built and flown within the British Commonwealth under conditions to be laid down by the Royal Aeronautical Society. These conditions will be announced shortly and the Royal Aero Club will be invited by the President of the Society, Mr. Peter G. Masefield, to act as official observers.

Mr. Kremer is enthusiastic about the work of the Man Powered Aircraft Group of the Society and he feels that the offer of a prize will provide the stimulus to achieve a successful first flight. The prize is offered personally by Mr. Kremer and the Society is most grateful to him.

The following is a copy of the letter announcing the Prize which was received by the President of the Society from Mr. R. Graham, C.B.E., *Fellow*, an Executive Director of Microcell Ltd., and a member of the Committee of the Man Powered Aircraft Group of the Society:

"I am very pleased to be able to inform you that Mr. Henry Kremer of 9 Kingsway, London W.C.2, Chairman and Managing Director of Microcell Limited and also a Director of B.T.R. Industries and other Companies, has most generously offered to give a prize of £5,000 (Five Thousand Pounds) for the first successful flight of a British designed, built and flown Man Powered Aircraft, such flight to take place within the British Commonwealth, under conditions laid down by the Royal Aeronautical Society.

Mr. Kremer has authorised me to write this letter and to say that information regarding this prize, and the conditions governing its award, may be made public at your convenience. *R. Graham.*

Fifth Air Transport Course, 1960—Oxford

The Fifth Air Transport Course held under the auspices of the Society will take place at Oriel College, Oxford, from 20th March to 9th April 1960 inclusive.

Brochures giving full particulars may be obtained on application to the Secretary of the Society at 4 Hamilton Place, W.1.

Branches Conference 1960

The Branches Conference will be held this year at the Brough Branch on Friday 29th and Saturday 30th April 1960. The tentative programme is for a reception on the Friday and a Conference and lunch on the Saturday.

President of the Institute of the Aeronautical Sciences

Lt. General Donald L. Putt (U.S.A.F., Retd.) has been elected President of the Institute of the Aeronautical Sciences in succession to Mr. William Littlewood.

Honours Awarded to Members

Sir George Edwards (*Fellow*), a past-president of the Society and Managing Director of Vickers-Armstrongs (Aircraft) Ltd., has been awarded The Daniel Guggenheim Medal.

The citation referred to Sir George's "lifetime devoted to the design of military and commercial aircraft, culminating in the successful introduction into world-wide commercial services of the first turbine-powered, propeller-driven aircraft."

Sir George is the fifth British recipient of this award.

The Rotorcraft Section

The Rotorcraft Section of the Society formally came into existence on 8th January 1960 when the merger of the Helicopter Association of Great Britain with the Royal Aeronautical Society became effective as a result of the Extraordinary General Meeting held on 8th January to wind up the Helicopter Association. The result of the voting by members of the Association on the resolution winding up the Association was:

In favour—133 Against — 21

The President and Council of the Society extend a warm welcome to the Helicopter Association and its members as the Rotorcraft Section of the Society and hope that this new Section will contribute as much to the science and operation of rotating wing aircraft as has the Helicopter Association.

The Executive Council of the Association has agreed to serve as the first Committee of the Rotorcraft Section as follows:—

Professor J. A. J. Bennett, D.Sc., Ph.D., D.I.C., F.R.Ae.S. (Professor of Aerodynamics, College of Aeronautics)—*Chairman.*

Squadron Leader B. H. Arkell, A.F.R.Ae.S. (Helicopter Consultant).

R. A. C. Brie, A.F.R.Ae.S., A.F.I.A.S. (Assistant to the Technical Director, Westland Aircraft Ltd.)

Captain J. A. Cameron (Head of Helicopter Experimental Unit, B.E.A.).

D. M. Davies, A.F.R.Ae.S. (Senior Project Engineer (Helicopters), Fairey Aviation Ltd.).

L. G. Frise, B.Sc., F.R.Ae.S., A.F.I.A.S. (Director of Special Projects, Blackburn Aircraft Ltd.—Member of Council, Royal Aeronautical Society).

M. H. C. Gordon (General Manager, Helicopter Division, Saunders-Roe Ltd.).

Raoul Hafner, F.R.Ae.S. (Chief Designer (Helicopters) Bristol Aircraft Ltd.).

J. S. Hislop, Ph.D., B.Sc., A.R.T.C., F.R.Ae.S., M.I.Mech.E. (Chief Engineer (Aircraft), Fairey Aviation Ltd.).

C. T. D. Hosegood (Chief Helicopter Test Pilot, Bristol Aircraft Ltd.).

N. J. G. Hill, A.R.Ae.S., A.M.I.Mech.E., G.Inst.T., M.C.A.I. (Head of Sales Division, Air Trainers Link Ltd.)

A. McClements (Design and Development Manager, (Helicopters) Bristol Aircraft Ltd.).

Colonel J. W. Richardson, A.F.R.Ae.S. (London Manager, Westland Aircraft Ltd.).

W. H. Sear (Chief Test Pilot, Westland Aircraft Ltd.).

J. S. Shapiro, A.F.R.Ae.S. (Consulting Engineer; Managing Director, Servo-Tec Ltd.).

D. L. Hollis Williams, B.Sc., F.R.Ae.S. (Technical Director, Westland Aircraft Ltd.).

R. H. Whitby, B.Sc., A.R.C.S., D.I.C., F.R.Ae.S. (Performance and Analysis Manager, B.E.A.).

Miss Rigby, formerly Assistant Secretary of the Helicopter Association, is joining the Staff of the Society.

The Society has agreed that members of the Helicopter Association joining the Society shall pay no entrance fee and shall be given credit for the unexpired portion of their Association membership.

The "Journal of the Helicopter Association of Great Britain" will cease publication with the issue of Number 6, Volume 13 (December 1959); the lectures and activities of the Rotorcraft Section—like those of the Society's other Sections and Groups—will be published in the Society's Journal.

Lectures arranged for the 1959-60 Session of the Helicopter Association will be given as lectures of the Rotorcraft Section; they are listed in the Diary and the summary of the first lecture (in February) is published in this issue.

DIARY

LONDON

21st January

MAIN LECTURE AT THE CAMBRIDGE BRANCH—Research at the College of Aeronautics, Cranfield. Professor A. J. Murphy. No. 1 Lecture Hall, Engineering Laboratories, Cambridge University. 8.15 p.m.

29th January

MAN POWERED AIRCRAFT GROUP LECTURE—Engineering Aspects of Man Powered Flight. B. S. Shenstone. Library, 4 Hamilton Place. 7 p.m.

2nd February

LECTURE—Suppression of Shock-Induced Separations by Boundary Layer Control. H. H. Pearcey. Library, 4 Hamilton Place. 7 p.m.

9th February

LECTURE—Model Testing in the Aircraft Research Association Co-operative Wind Tunnels. E. C. Carter. Library, 4 Hamilton Place. 7 p.m.

12th February

AGRICULTURAL AVIATION GROUP LECTURE—Choice of Aerial Vehicle. D. F. Myres and J. F. R. Britten. Library 4 Hamilton Place. 7 p.m.

17th February

MAIN LECTURE AT THE BRISTOL BRANCH—Firestreak. G. H. F. Brown. Conference Room, Filton House, Bristol Aircraft Ltd. 6 p.m.

23rd February

LECTURE—Relationship Between Theory and Practice in Structural Problems. A. J. Troughton. Library, 4 Hamilton Place. 7 p.m.

24th February

MAN POWERED AIRCRAFT GROUP LECTURE—Natural Flight. Peter Scott. Library, 4 Hamilton Place. 7.30 p.m.

ASTRONAUTICS AND GUIDED FLIGHT SECTION

18th February

Missile Control Problems. D. Best. Institution of Mechanical Engineers, Birdcage Walk, S.W.1. 6 p.m. (Tea at 5.30 p.m.)

GRADUATES' AND STUDENTS' SECTION

27th January

Problems and Prospects in British Aviation. Peter G. Masefield. Library, 4 Hamilton Place. 7.30 p.m.

24th February

Annual General Meeting and Film Show. Library, 4 Hamilton Place. 7.30 p.m.

ROTORCRAFT SECTION

5th February

Vertical Transport Business. Robert L. Cummings, Jr. Library, 4 Hamilton Place. 6 p.m.

4th March

British Research on the Aerodynamics of Powered Lift Systems. J. Williams. Library, 4 Hamilton Place. 6 p.m.

BRANCHES

21st January

Cambridge—MAIN SOCIETY LECTURE—Research at Cranfield. Professor A. J. Murphy. No. 1 Lecture Hall, Cambridge University Engineering Laboratories. 8.15 p.m.

Isle of Wight—Aircraft Production. A. Vines. Clubhouse, Saunders-Roe Sports and Social Club, Church Path, East Cowes. 6 p.m.

25th January

Henlow—Flying Boats. R. Stanton-Jones. The Assembly Hall, R.A.F. Technical College, Henlow. 7.45 p.m.

27th January

Hatfield—Development of the Handley Page Victor. C. F. Joy. de Havilland Restaurant. 6.15 p.m.

Southampton—The Rotodyne. Dr. G. S. Hislop. Engineering Lecture Theatre, University of Southampton. 8 p.m.

Weybridge—Flight Testing at Supersonic Speeds. Wing Cdr. Beamont. Apprentice Training School, Vickers-Armstrongs (Aircraft) Ltd. 6.10 p.m.

28th January

Belfast—Aircraft in the Modern Army. Major D. W. Leach. Lecture Hall LG8, David Keir Building, Queen's University. 7 p.m.

29th January

Chester—Annual Dance. Quaintways Restaurant, Chester.

Merthyr Tydfil—Film Show.

1st February

Boscombe Down—Long Range Missiles. E. C. Cornford. Lecture Hall, A. & A.E.E. 5.30 p.m.

Derby—Ten-Minute Paper Competition and Films. Rolls-Royce Welfare Hall, Nightingale Road. 6.15 p.m.

2nd February

Bristol—Junior Committee Lecture. Air Traffic Control. R. Woodruffe. Filton House. 6 p.m.

Luton—Development of the Rotodyne. Dr. H. F. Winny. Napier Senior Staff Canteen, Luton Airport. 6.15 p.m.

3rd February

Brough—Production of the "Saladin" Armoured Car. H. J. Nixon. Royal Station Hotel Writing Room. 7.30 p.m.

Christchurch—Glass. Dr. Holland. King's Arms Hotel. 7.30 p.m.

Swindon—Beating the Heat Barrier. J. Taylor. The College, Victoria Road. 7.30 p.m.

4th February

Isle of Wight—Agricultural Aviation Practices and Development. F. R. J. Britten. Clubhouse, Saunders-Roe Sports and Social Club, Church Path, E. Cowes. 6 p.m.

London Airport—Second Sir Richard Fairey Memorial Lecture. L. Boddington. Senior Mess Club, B.O.A.C. H.Q. 7 p.m.

Yeovil—Lecture. Park School, Park Road. 7.30 p.m.

8th February

Glasgow—Graduates' and Students' Section—Visit to *Glasgow Herald* Newspaper Works. 7.30 p.m.

Henlow—Strategic Air Command, by a member of the 7th Air Division, U.S.A.F. The Assembly Hall, R.A.F. Technical College, Henlow. 7.45 p.m.

9th February

Cambridge—The Development of the Rotodyne. Dr. G. S. Hislop. No. 1 Lecture Hall, Cambridge University Engineering Laboratories. 8.15 p.m.

10th February

Chester—Joint Meeting with Stanlow Branch of the Institute of Petroleum—Bitumen and its Application to Runways. G. P. Jackson. Lecture Theatre, Grosvenor Museum. 7.30 p.m.

11th February

Cheltenham—Some Problems of Satellites for Scientific Purposes. Dr. A. W. Lines. St. Mary's College. 7.30 p.m.

15th February

Derby—The Use of Rockets in Scientific Research. Prof. H. S. W. Massey. Rolls-Royce Welfare Hall, Nightingale Road. 6.15 p.m.

Halton—Parachutes. S. B. Jackson. Branch H.Q., R.A.F. Halton. 6.45 p.m.

16th February

Glasgow—Pilcher Memorial Lecture—History of Development of Airlines in Scotland. Capt. E. A. Starling. Royal College of Science and Technology. 7.15 p.m.

17th February

Bristol—MAIN SOCIETY LECTURE—Firestreak. G. H. F. Brown. Conference Room, Filton House, Bristol Aircraft Ltd. 6 p.m.

Coventry—Aircraft Electrical Systems. G. G. Wakefield. Herbert Art Gallery. 7.30 p.m.

Preston—Joint Lecture with Institute of Welding. The Application of Special Purpose Machine Tools. I. T. Clowes. R.A.F.A. Hall. 7.30 p.m.

Southampton—Some Aspects of Yacht Performance Analysis. P. Crew. Engineering Lecture Theatre, University of Southampton. 8 p.m.
Weybridge—Supersonic Transport. P. A. Hufton. Apprentice Training School, Vickers-Armstrongs (Aircraft) Ltd. 6.10 p.m.

19th February
Birmingham and Wolverhampton—The Rolls-Royce Tyne Engine. D. Maclean. The Engineering Centre, Birmingham. 7.30 p.m.

22nd February
Cambridge—Film Show. No. 1 Lecture Hall, Cambridge University Engineering Laboratories. 8.15 p.m.
Halton—Third Trenchard Memorial Lecture. "A Dip into the Future . . . ." Sir George Edwards. Burnett Gymnasium, R.A.F. Halton. 6.45 p.m.

24th February
Christchurch—Man Powered Aircraft. B. S. Shenstone. Kings Arms Hotel. 7.30 p.m.
Hatfield—The S.R.N1 Hovercraft. R. Stanton-Jones. de Havilland Restaurant. 6.15 p.m.
Reading—The Car Ferry Operation and History of Silver City Airways. M. D. Day. Top Canteen, Western Manufacturing (Reading) Ltd. 6 p.m.

25th February
Belfast—Blind Landing. W. J. Charnley. Lecture Hall LG8, David Keir Building, Queen's University. 7 p.m.
Bristol—Junior Committee Lecture. The SR.N1 Hovercraft. R. Stanton-Jones. Filton House. 6 p.m.
Isle of Wight—The Economic Basis for the Design of a Freight Aircraft. A. H. Stratford. Clubhouse, Saunders Roe Sports and Social Club, Church Path, E. Cowes. 6 p.m.

29th February
Yeovil—5th Henson and Stringfellow Memorial Lecture—VTOL Aircraft. D. Keith-Lucas. Park School, Park Road. 7.30 p.m.

1st March
Luton—An Historical Lecture. C. F. Uwins. Lecture Hall, Luton College of Technology. 7 p.m.

2nd March
Brough—The Boeing 707. J. Sutter. Royal Station Hotel Writing Room. 7.30 p.m.
Preston—The Fairey Rotodyne. Dr. G. S. Hislop. R.A.F.A. Hall, Preston. 7.30 p.m.
Swindon—Flight Testing of Modern Prototype Aircraft. C. F. Bethwaite. The College, Victoria Road. 7.30 p.m.
Weybridge—Space Flight. Discussion by a panel of experts. Apprentice Training School, Vickers-Armstrongs (Aircraft) Ltd. 6.10 p.m.

Sir Henry Tizard

Professor P. M. S. Blackett, F.R.S., F.R.Ae.S., will deliver a lecture entitled "Henry Tizard and the Science of War" at the Royal Society of Arts on 11th February 1960.

Tickets may be obtained from the Secretary, Royal Society of Arts, 6 John Adam Street, Adelphi, W.C.2.

Civil Aircraft Accident Investigation Procedure

The Minister of Aviation, Mr. Duncan Sandys, has set up a committee to review the civil aircraft accident investigation procedure and the conditions under which the licences of flight crew or maintenance engineers may be cancelled or suspended.

Sir David Cairns, Q.C., will be Chairman of the committee and the other members are:— Sir Frederick Tymms, *Fellow*, Mr. W. L. Heywood, Mr. Peter G. Masefield, *Fellow* (President of the Society) and Mr. H. C. I. Rogers.

The committee is willing to consider written evidence from anyone wishing to comment, and memoranda should be sent to E. J. Martin, Esq., Ministry of Aviation, Room 3000C, Berkeley Square House, London W.1.

Past Presidents of the Society

On Tuesday 8th December, the President gave a dinner to Past Presidents of the Society which was attended by the following:—

Major G. P. Bulman
Sir John Buchanan
Sir Sydney Camm
Sir George Edwards
Sir William Farren
Sir Roy Fedden
Sir Arthur Gouge
Sir Arnold Hall
Mr. E. T. Jones
Sir Frederick Handley Page
Mr. N. E. Rowe

Dr. A. M. Ballantyne and Captain J. Laurence Pritchard were also present.

Mr. Alec Ogilvie, Mr. H. E. Wimperis, Lord Brabazon, Lord Sempill and Sir George Dowty were unable to be present.

A copy of the Menu was autographed by all those present and has been placed in the archives of the Society with many items of a similar nature now in the Society's records.

Discussion on Soviet Control Engineering Progress

The Measurement and Control Section of The Institution of Electrical Engineers will hold a discussion on "Soviet Control Engineering Progress" on 16th February 1960. The discussion will be opened by Mr. R. E. Clark and Professor A. Tustin, who led the British team which visited Russia in May 1959 to study progress in automatic control applied to industrial production, will be Chairman of the meeting.

Tickets may be obtained from W. K. Brasher, Secretary, The Institution of Electrical Engineers, Savoy Place, London W.C.2.

The Exploration of Space

The Department of Extra-Mural Studies, University of London, is to hold a course of ten University Extension Lectures on The Exploration of Space, a review for the non-specialist from 19th January to 22nd March 1960. The lectures will be held at the City Literary Institute, on Tuesdays at 6 p.m.

The fee for admission is 8s. Further details and application forms may be obtained from the Principal, City Literary Institute, Stukeley Street, London W.C.2.

Annual Subscriptions

Members are reminded that their annual subscriptions became due on 1st January 1960. The rates are:—

	Home £ s. d.	*Abroad* £ s. d.
Fellows	8 0 0	7 0 0
Fellows (over 65)	5 0 0	4 0 0
Associate Fellows	6 0 0	5 0 0
Associate Fellows (over 65)	4 0 0	3 0 0
*Associates	5 0 0	5 0 0
Associates (over 65)	3 0 0	3 0 0
Graduates (aged under 26)	2 10 0	2 10 0
Graduates (aged 26 and over)	3 0 0	3 0 0
Students (aged under 21)	1 10 0	1 10 0
Students (aged 21 and over)	2 0 0	2 0 0
Companions	4 0 0	4 0 0
Companions (over 65)	3 0 0	3 0 0
Companions (No Journal)	2 10 0	2 10 0
Founder Members	— — —	— — —

*Any Associate elected before 1st October 1947 may, if he wishes, elect not to receive the JOURNAL, and in this case his subscriptions will be reduced by £1 10s. 0d. to £3 10s. 0d.

It will avoid delay and confusion if members, when sending remittances for subscriptions, will state their names clearly and give their addresses and grades of membership. Remittances should be made payable to the Royal Aeronautical Society.

Elections

The following is a list of elections and transfers of membership of the Society:—

Associate Fellows

Thomas Eric Bateman (*from Graduate*)
Arthur Sidwell Bennett (*from Graduate*)
Alastair Anderson Brown
Conway Andrew James Chiles (*from Graduate*)
Robert James Clayton
Stanley Harold Dance (*from Graduate*)
David Darling
Man Mohan Nath Dube
William Richard Hardman
Reginald Grant Hodges
Desmond Peter Howlett (*from Graduate*)
Arthur Albert Jacobs (*from Graduate*)
Eric Alexander Robert Jolly (*from Associate*)
Anthony Charles Johnson
Arthur Albert Keeler (*from Graduate*)
Donald Thomas Lincoln (*from Graduate*)
Peter James Marsh
Jack Watkin Miller
Thomas De Burgh Miller
Patrick Ian Normand
John Lloyd Hendy Phillips (*from Graduate*)
Kenneth Martin Reed
Richard Brian Stratton (*from Associate*)
Allan Taylor (*from Graduate*)

Associates

Lewis Frederick Bateman (*from Companion*)
Brian John Bolton
Alfred Gerald Bryant
Francis William Carnell
Arthur Donald Cross
Herman Hendrik Dalman (*from Student*)
Stanley John Evans
Charles Michael Gallen
David Noel Howard
Cecil Daniel Leslie
Sivaramannair Kesavan Nair (*from Student*)
Donald Richard Noble
William Charles Price
John Ronald Probert
Herbert Rawlinson
Norman James Williams

Graduates

Alan Terence Boyd (*from Student*)
Christopher John Buckland
John Keith Burningham
Charles Desmond Cross
Roger John Gabriel (*from Student*)
Terence William Fitzgerald Moore
Francois Paulus Naude
Keith Harvey Munro Noble
Terence Graham Pearce
Peter Gordon Stevens (*from Student*)
Peter Stanley Stevens
Ronald Patrick Taylor
A. S. Viswanathan
John Frederick Waterhouse

Students

William George Bradley
David Martin Brown
Duncan Campbell Deeble
Andrew James Gardiner
Malcolm Skeolan Hackett
John Frederick Hahn
Raymond John Hale
Beryl Hulley
Rowland Peters Jones
Anthony John Lawler
Terence Long
David Marsh
Trevor Holmes Moulden
Ronald Graham Peasley
Bryan Edward Richards
Brian Sidney Riley
Alexander McDonald Ramsay
Robert George Salvage
Michael John Tickner
Julian Wilfred Ward
Richard Taylor Webster
Frank William Whipp
Anthony John Wickstead
Dudley Martin Williams

Companion

Colin John Healey

News of Members

J. R. Anderson (*Associate Fellow*) formerly Senior Scientific Officer, Royal Aircraft Establishment, Bedford, is now Chief Superintendent of Wind Tunnels, Sir W. G. Armstrong Whitworth Aircraft Ltd., Whitley.

Eric M. Bell (*Associate*) has returned from the U.S.A. and is now a Design Engineer with Vickers-Armstrongs (Aircraft) Ltd., Weybridge.

Sqn. Ldr. C. L. Bessey (*Associate Fellow*) formerly Supplies Superintendent (New Projects) B.O.A.C. London Airport, is now Planning Controller (Engineering and Maintenance).

Dr. J. Black (*Associate Fellow*) has been appointed Head of the Department of Aeronautical Engineering, Bristol College of Technology (designated a College of Advanced Technology from September 1960) and has resigned from his post of Senior Lecturer in Aeronautical Engineering, University of Bristol.

W. J. Bootle (*Associate Fellow*) formerly with National Presto Industries, Eau Claire, Wisconsin, is now a Senior Weapons Systems Engineer, Aeronca Manufacturing Corporation, Middletown.

M. G. Cherry (*Graduate*) formerly Thermodynamics Engineer, Aerodynamics Department, Orenda Engines Ltd., Canada, is now Preliminary Design Engineer, Aerodynamics Group, AiResearch Manufacturing Company, California.

S. A. Clarke (*Associate Fellow*) formerly a Lecturer in Aeronautical and Mechanical Engineering, Coventry Technical College, has been appointed Principal Education Officer (Technical), Ministry of Education, Ghana.

Flying Officer Brian Cooper (*Graduate*) formerly with de Havilland Aircraft Co. Ltd., is now Education Officer at the No. 1 School of Technical Training, R.A.F. Halton.

P. K. Digby (*Associate Fellow*) formerly a member of the Director's Personal Staff of the Production Engineering Research Association, has been appointed Manager of the new department of Management Economics.

Wing Cdr. D. G. Dunphy (*Associate Fellow*) formerly Senior Technical Officer at R.A.F. Honnington, is now on the Engineering Staff of H.Q., Middle East Air Force.

R. Foster (*Associate Fellow*) formerly an Experimental Officer, M.O.S., is now in the Engine Research and Development Division, Eng.R.(C.), Ministry of Aviation.

Sqn. Ldr. P. H. Francis (*Associate*) formerly at R.A.F. Carlisle, is now with the Air Ministry, London (Central Work Study Unit).

Roger H. Godfrey (*Associate*) formerly with Convair, San Diego, is now a Senior Design Engineer, Beech Aircraft Corporation of Wichita, Kansas.

E. M. Goodger (*Associate Fellow*) formerly at The College of Aeronautics, Cranfield, is now Associate Professor and Head of the Engineering Department, Newcastle University College, New South Wales, Australia.

R. W. V. Grandorge (*Associate Fellow*) formerly with Bristol Siddeley Engines Ltd., Coventry, is now with the Ministry of Aviation, Eng.R.D.3.

Sqn. Ldr. R. B. Griffiths (*Associate Fellow*) formerly in the Directorate of Aircraft Engineering at the Air Ministry has retired from the Royal Air Force and is now a Standards Engineer with English Electric Aviation Ltd. (Guided Weapons Division) at Stevenage.

Peter Hampton (*Graduate*) was awarded in October 1959 the Degree of Master of Science in Engineering (M.S.E.) by Princeton University and has been appointed Scientific Officer at the R.A.E. Farnborough.

L. J. Hansford (*Associate*) formerly Chief Inspector of Edgar Percival Aircraft Ltd., has now been appointed Production Manager of the company which has now been named the Lancashire Aircraft Company Ltd.

W. J. Harbottle (*Associate Fellow*) formerly with Roberts & Wootton Ltd., has joined Air Couriers Ltd., to form and head a Design Department.

Pilot Officer A. J. Harland (*Graduate*) formerly in the Stress Office of H. M. Hobson Ltd., Wolverhampton, is now Technical Wing Adjutant, R.A.F., Linton-on-Ouse.

Brian Dutton Henshall (*Associate Fellow*) formerly in the Hypersonic Research Group of the Aerodynamics Division, N.P.L., is now Head of the Special Projects Group, Weapons Research Division, A. V. Roe and Co. Ltd., Woodford.

C. G. Hollowell (*Associate*) formerly Public Relations Manager with D. Napier and Son Ltd., Acton, is taking up a similar position with the English Electric Company Ltd., at Marconi House.

Michael G. Howard (*Student*) on obtaining his Degree of B.Sc.(Eng.), University of London is now with Hawker Aircraft Ltd. as a Post Graduate Trainee.

D. N. Hunter (*Companion*) formerly Chief Plastics Technologist, D. Napier and Son Ltd., Luton, is now with Messrs. Artrite Resins Ltd., Research Laboratories, Camberley as Senior Research Chemist.

G. N. LANCE (*Associate Fellow*) formerly Director of the computation laboratory, University of Southampton, is now in charge of the newly formed computer group at the Atomic Energy Establishment, Winfrith Heath, Dorset.

G. J. MALIN (*Associate Fellow*) has been promoted to Assistant Director in the Directorate of Aircraft Production, Ministry of Aviation.

J. F. MESTON (*Associate*) formerly with International Aeradio Ltd., is now a Senior Engineer in the E.M.I. Group in the Sales and Services Ltd. Division.

F. MURPHY (*Associate Fellow*) formerly R.A.F. Liaison Officer (Flying) to Hawker Aircraft Ltd., is now Foreign Sales Manager for Hawker Aircraft Ltd.

RONALD E. NUTLEY (*Associate*) formerly with de Havilland Propellers, is now Sales Engineer at A.P.V. Paramount Ltd., Crawley.

P. C. PARKS (*Graduate*) formerly in the Guided Weapons Engineering Department, Bristol Aircraft Ltd., has been appointed to a Lectureship in the Department of Aeronautics and Astronautics, University of Southampton.

J. POOLE (*Associate Fellow*) formerly head of the High Supersonic Speed Tunnel at R.A.E., Bedford, is now Superintendent of the Airborne and Helicopter Division, A. & A.E.E.

F. K. POULTON (*Associate Fellow*) formerly with the Fairey Company, is now Assistant to the Production Executive, Plessey Company, Swindon.

K. SIMCOX (*Student*) formerly a Technician with Dowty Equipment Ltd., Cheltenham, is now Servo Production Manager.

Eng. Lt. N. C. R. SINNOTT (*Associate*) formerly at the Ministry of Aviation (Eng.R.D.), is now at the R.N. Air Station, Yeovilton, Somerset, for Engineering Duties.

L. W. STEVENS-WILSON (*Companion*) formerly Head of the Development and Steel User Section, British Iron and Steel Research Association, is now Head of the newly-formed Development and Information Services unit.

P. H. TOWNSHEND (*Associate Fellow*) formerly Eng.A. Structural Test (Research and Development Dept.), Canadair Ltd., is now in the Mechanical Test Laboratory of Armstrong Whitworth, Coventry.

Rear Admiral A. J. TYNDALE-BISCOE (*Fellow*) has retired from the Royal Navy and has been appointed a Divisional Director with Messrs. Blaw-Know Ltd.

T. WAYNE (*Associate Fellow*) formerly Assistant Sales Manager (Aero), Rolls Royce of Canada Ltd., Montreal, is now engaged upon Technical liaison duties for Rolls-Royce of Canada Ltd. at Derby.

Summaries of Lectures

FUTURE OF AUTOMATIC CONTROL ON FIXED WING AIRCRAFT

by

Professor G. A. WHITFIELD, B.Sc., F.R.Ae.S., F.Inst.P., M.I.E.E.

(*Professor of Aircraft Electrical Engineering, The College of Aeronautics*)

Given on 14th January

Up to the present time, automatic controls have not been an essential part of an aircraft and the safety of the aircraft has not depended on their successful functioning. If they were sufficiently reliable and were treated as an essential part, very considerable advantages would accrue. The performance of various component parts suggests that if it were desired to do so, it would be possible to design auto-controls to be so reliable that the safety of the aircraft could be allowed to depend on their functioning. This would be so, particularly if, as may well be the case, a proportion of fatal accidents would be avoided by the resulting improvements of the handling characteristics.

SOME AERODYNAMIC PROBLEMS OF ENGINE INSTALLATION

by

Dr. J. SEDDON, Ph.D., B.Sc., F.R.Ae.S., A.F.I.A.S.

(*Head of Tunnels II Division, Royal Aircraft Establishment, Bedford*)

Given on 19th January

The increasing importance of engine installation as a factor in the overall aerodynamic assessment of an aircraft is stressed. The lecture does not attempt to review the complete situation but discusses some of the vital aerodynamic problems. Chief among these are:—

(1) Boundary layer effects in the intake.
(2) Some considerations of installed drag.
(3) Some interesting aspects of base flow.

RESEARCH AT THE COLLEGE OF AERONAUTICS, CRANFIELD

by

The Principal,
Professor A. J. MURPHY, M.Sc., F.I.M., F.R.Ae.S.
and the Staff of the College of Aeronautics, Cranfield

Given on 21st January

Instruction in the College of Aeronautics is at post-graduate level and research is undertaken by staff and students, publication being mainly in "Reports" or "Notes" of the College. Each student writes a thesis on his research.

In aerodynamics, principal topics of research have been jet noise, interference at supersonic speeds, slender wings and bodies at low subsonic speeds, jet lift, blade flutter, hypersonics including theoretical work on real gas effects, gases, ablation and magnetogasdynamics. Experimental facilities include wind tunnels for speeds up to a Mach number of 3, a freon tunnel and shock tubes for hypersonic speeds. A helium hypersonic wind tunnel is in course of construction.

Research on design studies of aeroplanes is achieved by co-operation between departments on specific projects, such as a low level bomber of Mach number 3.

In connection with structures, experimental research has been directed to the verification of mathematical theories which have been developed relating to stress distribution, buckling and fracture under both static and fatigue conditions. Special attention has been devoted to delta and other low ratio wings, stress distribution in pressure cabins and thermal effects on structures. A continuing study on the buckling of stressed skin and sandwich construction has been directed to the effect of plasticity on the buckling of plates in shear and on the stress distribution in problems of contained plasticity.

The optimum layout of framed and plate structures has been theoretically investigated.

In aircraft propulsion, mechanical research is concerned with the dynamic loading of gear teeth, bearings and the whirling of complex rotors. Aerodynamic research includes work on the effect of ground proximity on the thrust produced from an engine delivering a downward jet. For detecting the flow pattern of the reacting gases in a rocket combustion

chamber a technique has been evolved by the extension of the aerodynamic smear technique using flame-sprayed zirconia. Spontaneous ignition of liquid fuels, pre-ignition in engines and flame stabilisation have been investigated.

In aircraft economics and production, research has been concerned with metal removal by cutting tools and techniques of control for the achievement of very high precision in production. Studies in economics have been directed to the relationship between the man-hours required to manufacture a series of aero engines and the number produced.

Aircraft electrical engineering research has been devoted to servo mechanisms, analogue computing, digital techniques, process control, electronics, U.H.F. and V.H.F. techniques, microwaves, motors, servo-components and power systems.

The main researches in aircraft materials have been related to metal fatigue with special reference to the micro-structural changes occurring in high strength aluminium alloys during the fatigue process. Technological researches have included the improvement of cast metals by mechanical vibration during solidification.

In mathematical research the wave drag of bodies in supersonic flow has been investigated, leading to the formulation of the "transfer rule" for calculating and minimising the wave drag of winged bodies, and to the "harmonic method" for dealing with drag calculations for both lifting and non-lifting bodies.

Research in flight testing has been concerned principally with dynamic stability, performance, and instrumentation. Measurements on boundary layer transition on a swept wing airborne above the fuselage of a Lancaster have been applied to a design study for laminar flow. Techniques have been developed and tested for measuring outside air temperature on a Hawker Hunter.

Man Powered Aircraft Group

ENGINEERING ASPECTS ON MAN POWERED FLIGHT

by

B. S. SHENSTONE, M.A.Sc., F.R.Ae.S., F.C.A.I., A.F.I.A.S.
(*Chief Engineer, British European Airways*)

To be given on 29th January

The lecture will deal with the engineering problems of man powered aircraft which are:—

(1) The arrangement of the structure.
(2) The details of the structure.
(3) Power transmission.

The arrangement of the structure is dealt with from the point of view of the best means of applying the power and the optimum position of wing. Some remarks about the effect of the main structural material on the layout of the aircraft are made.

The weight problems are dealt with from the point of view of calculating the proper weights of structure for man powered aircraft by deriving these from existing weights of aircraft already built for man power and some existing sailplanes.

The details of the structure are surveyed from the point of view of the differences between the scale of the man powered aircraft structure and the scale of other light-weight aircraft, bringing in the possibilities of unusual materials and combinations of materials.

The power transmission problems are dealt with in general fashion because in the absence of a particular design, such problems cannot be dealt with in detail.

The problems of shafting, calculating propeller speeds and wheel drive during take-off are considered.

The lecture will be illustrated by slides.

SUPPRESSION OF SHOCK-INDUCED SEPARATIONS BY BOUNDARY LAYER CONTROL

by

H. H. PEARCEY
(*Aerodynamics Division, National Physical Laboratory*)

To be given on 2nd February

The use of boundary layer control to increase the separation-free margins of Mach number and lift coefficient beyond the cruise point of high-speed aircraft may often be preferred to design changes that impair the cruising performance or the landing and take-off characteristics. The factors that influence the choice of method and details of its application will be discussed, emphasising particularly the need to maintain effectiveness over most of the chord to cover the wide range of separation positions encountered as the shock wave moves over the wing with changing flight conditions.

Research at the National Physical Laboratory that has embraced high-velocity blowing, vane and air-jet vortex generators, and, in a preliminary way, distributed suction, will be described briefly. The relative merits of the various methods will be discussed, and some results given to illustrate the benefits achieved from their application.

Rotorcraft Section

VERTICAL TRANSPORT BUSINESS

by

ROBERT L. CUMMINGS, Jr.
(*President, New York Airways, Inc.*)

To be given on 5th February

Turbine-powered helicopters mark the transition from *experiment* to *business* for that segment of the transportation industry which requires the capability for vertical flight.

Completing more than a year of detailed study and evaluation, New York Airways recently announced its intention to purchase ten such aircraft designed to cruise in excess of 150 miles per hour with 25 passengers. They will be introduced into service in the spring of 1961. With these machines commercial revenues could, for the first time, offset all operating charges including taxes and a fair return on the capital investment.

The availability of the Fairey Rotodyne in 1964 will place New York Airways in a position to offer the public a substantially enlarged and even more useful service operating on a business basis.

MODEL TESTING IN THE AIRCRAFT RESEARCH ASSOCIATION CO-OPERATIVE WIND TUNNELS

by

E. C. CARTER
(*Deputy Chief Aerodynamicist, Transonic and Supersonic Tunnels, Aircraft Research Association*)

To be given on 9th February

Research and development testing at the Aircraft Research Association is reviewed. The design, range and special features of the transonic and supersonic wind tunnels are briefly discussed and mention is also made of the organisation, financial aspects and the utilisation of the facilities.

The handling of routine tests is discussed considering also the instrumentation and computing facilities installed for data processing. Special tests for research and development are considered describing special instrumentation techniques and flight simulation conditions, *e.g.* flow visualisation and measurement of flow direction.

The development of some special rigs for jet efflux tests, flutter and internal drag measurements are briefly mentioned, and some ideas are given on extensions of the range of the A.R.A. facilities in the light of present and future demand.

The Journal of the Royal Aeronautical Society

WITH WHICH IS INCORPORATED THE INSTITUTION OF AERONAUTICAL ENGINEERS

VOLUME 64 JANUARY 1960 NUMBER 589

The Fifteenth British Commonwealth Lecture

Some Recent Progress in Air Survey

With Particular Reference to Newly-Developed Territories

BY

W. P. SMITH, M.B.E., B.A., F.R.I.C.S.

(Director, Fairey Air Surveys Ltd.)

The Fifteenth British Commonwealth Lecture "Some Recent Progress in Air Survey with Particular Reference to Newly-Developed Territories" was given by W. P. Smith, M.B.E., B.A., F.R.I.C.S. before the Royal Aeronautical Society at the Institution of Mechanical Engineers on 19th November 1959. Mr. Peter G. Masefield, M.A., F.R.Ae.S., Hon.F.I.A.S., President of the Society, presided. Introducing the Lecturer the President said: This lecture was the second of their four premier named annual lectures. The first was the traditional Wilbur Wright Lecture, the second this Commonwealth Lecture, the third was the Louis Blériot Lecture and the fourth the Lanchester Memorial Lecture. Five years ago, as many of them would recall, His Royal Highness, Prince Philip, the Duke of Edinburgh, honoured them by giving the Commonwealth Lecture on "Aviation and the Development of Remote Areas." He thought that they could say that the subject of Mr. Smith's Commonwealth Lecture was in some ways a projection of the Duke of Edinburgh's lecture, under the title "Some Recent Progress in Air Survey with Particular Reference to Newly-Developed Territories."

Mr. W. P. Smith was a Director and leading light of Fairey Air Surveys Limited. Naturally as befitted a Commonwealth Lecturer, Mr. Smith was a master of his subject—one could almost say that he was "monarch of all he surveys." He was a Durham man, born in 1920; he was educated at Wellfield School, Durham, and went up to Oxford and took his degree there. During the War, Mr. Smith was in command of Survey Units in the Royal Engineers and after the War he transferred to the Survey Branch of the Control Commission, in Germany. Then, in 1946 he left the Army to join the new Directorate of Colonial Surveys as a Senior Surveyor, and went to West Africa on the Volta River Project. He worked in Africa for a period and then in 1950 he joined Fairey Air Surveys Limited, then known as the Air Survey Company, as many would remember. He was a General Manager then, and was now a Director. So Mr. Smith had spent all his working life dealing with the subject on which he was going to talk about that evening, and in particular, he had been in charge of that vast Kariba Hydro-Electric Survey, on the Zambesi. They could have no one better to talk about Air Survey, and it was said that "life is the art of drawing sufficient conclusions from insufficient premises." Air Survey, and the sort of things Mr. Smith was going to talk about was, in some ways, a way of filling in some of those insufficiencies.

He had much pleasure in calling on Mr. Smith to deliver the Fifteenth British Commonwealth Lecture.

IN THE TENTH British Commonwealth and Empire Lecture delivered to this Society, your distinguished Honorary Fellow, H.R.H. The Duke of Edinburgh, drew attention to the range and importance of tasks undertaken by aviation in the remote areas of the Commonwealth. Among these he mentioned aerial surveying, and it is an honour both to the surveying profession and to myself that this Fifteenth Commonwealth Lecture should be concerned solely with this aspect of aviation.

The main topics of the paper will be: —

- Progress in aerial surveying cameras.
- Aircraft, and navigational methods.
- Some applications of the photograph: geology, forests, and agriculture.
- Air survey as applied to mapping: some uses in newly developing areas.
- Airborne electronic aids designed to reduce the need for ground framework control.
- Airborne geophysical survey as an aid to mineral prospecting.

By way of preface it may be emphasised that topographical survey has seldom been popular in the past as a subject of government expenditure, except in the tangible form of completed maps. Maps prepared by classical methods took long to produce, were expensive, and were consequently frequently omitted from development plans. There are many failures of development projects in remote areas which can be attributed directly or indirectly to the absence of such maps.

Air survey makes its most significant contribution to this situation by offering two bites at the cherry. The first, the aerial photograph, is cheap, needs no access to the ground, provides a stereoscopic impression of relief which is far more vivid than could be obtained by visual aerial reconnaissance, and records permanently both visible topographical detail and other specialist information capable of interpretation by experts. If the results of initial appraisal are unsatisfactory, the development project can stop at this point, with minimum expenditure. If not, then the second and much more expensive bite can be taken, and contoured surveys made from the aerial photography, supplemented by ground framework control.

In general, there is now no longer any excuse for undertaking major development of land and natural resources without adequate survey.

Aerial Photography

Much useful air survey work was done between the wars. In Canada there was a library of 700,000 photographs in existence by 1936. K.L.M. photographed 98,000 square kilometres in New Guinea in the two years between 1935 and 1937. Robbins of South Africa made some of the earliest photographic surveys in the Rhodesias, while in Australia in 1935 Wing Commander (now Group Captain) Laws undertook the air survey of some 80,000 square miles in Western Australia as part of a contract between the Western Mining Corporation and H. H. Hemming and Partners. The equipment available was generally simple in design but the results easily bear comparison in pictorial quality with much present-day photography.

From a survey point of view, much was to be desired, and it was not until after Group Captain Laws' return from Australia that the first truly survey cameras, with rigid lens/focal-plane location, were produced in this country. These were the Eagle V, Eagle VII, and Eagle IX. A descendant of the latter is still in use by the R.A.F. under the name of F49 Mk. II. But war came in 1939, the Eagle IX was not immediately ready for use, and at the end of the war in 1945 the only proven survey camera available was the American K17, incorporating the Metrogon wide-angle survey lens, focal length 6 in., a between-the-lens shutter, and a vacuum film flattening system over a 9 in. square format.

At this point, when the K17 camera was taken into extensive use by the R.A.F. in their one and a quarter million square mile programme of photography of the British Colonies, and was adopted, largely by virtue of its availability, by many governments overseas, one may question whether geologists and others concerned with qualitative interpretation had really gained so much by the passage of time. Certainly much of the photography then achieved was inferior to the products of pre-war cameras of longer focal length. Yet the extent of the cover was some compensation for the fall-off in pictorial quality and the camera represented at least some progress towards meeting the surveyors' specification. Unfortunately, experience was to show that much of this basic Colonial photography was of limited value for photogrammetric mapping and it has had to be repeated by more deliberate methods.

Progress in Aerial Surveying Cameras

The most important step forward in air survey since 1946 has been the design and introduction of a new type of survey lens, typified by the Aviogon 150 mm. objective of L. Bertele. This lens combines exceptional resolving power (better than 50 lines per mm. on axis). very low distortion (not exceeding 0·010 mm.), total and marginal illumination markedly superior to that of earlier Ross and Metrogon lenses, and wide angular coverage (Fig. 1).

The introduction of this lens, of high pictorial quality, short focal length, and to the most rigid survey specification, represents a spectacular leap forward to a new order of quality. It has been adopted throughout the Commonwealth and any appraisal of progress made

FIGURE 1. The optical unit of a "Wild" RC5A Aerial Camera incorporating the Aviogon wide-angle survey lens.

in air survey must recognise its introduction as a major landmark. Repercussions have been many and varied.

Of first importance, improved resolution has stimulated a trend towards smaller scales in photography. These imply increased flying heights and provide increased cover per exposure. Table I gives comparative statistics for a rectangular area of 40,000 square miles at scales of (*a*) 1 : 30,000 (a compromise scale frequently adopted for the earlier types of lens, to meet the needs of both interpreter and map maker), (*b*) 1 : 40,000, as now adopted extensively with the Aviogon type lens, requiring a flying height of 20,000 ft. above ground level, and finally (*c*) 1 : 80,000, which some authorities feel may be the scale for the future, using high speed turbo-jet aircraft at altitudes of 40,000 ft. The last line (*d*), for interest, gives figures which the Western Australian Survey, noted earlier, might have hoped to achieve using Dragon aircraft of 14,000 ft. ceiling, and the 1935 Eagle IV camera of $6\frac{1}{2}$ in. × $8\frac{7}{8}$ in. format.

In this country, all photographic programmes arranged for the Colonies by the Directorate of Overseas Surveys now require a scale of 1 : 40,000, instead of 1 : 30,000 which was customary when Eagle IX cameras were in use, while in Canada, the Interdepartmental Committee on Air Surveys has recently specified a photographic scale of 1 : 60,000 for work in the Arctic.

We shall see later how accuracy of photogrammetric mapping has been increased, using the new lens. At this point it would be well to note some more immediate repercussions affecting camera design and photographic operations overseas.

TABLE I

Scale	Focal length	Aircraft height above ground	Per 40,000 sq. miles: No. of exposures	Per 40,000 sq. miles: Line miles of photography
(*a*) 1:30,000	6 in.	15,000 ft.	7,800	13,400
(*b*) 1:40,000	6 in.	20,000 ft.	4,360	10,000
(*c*) 1:80,000	6 in.	40,000 ft.	1,090	4,650
(*d*) 1:17,000	10 in.	14,000 ft.	33,500	23,400

Improved lens efficiency in terms of light transmission, extends the hours of "photographic daylight," and over such areas as the rain forests of British Guiana and the Southern Cameroons, photography can now be undertaken during the marginal lighting conditions of early morning, which are occasionally cloud-free. This can result in such areas being photographed for the first time. In better weather areas, where photographs can be taken during the middle part of the day, advantage may be taken of the same improvement in lens design to use much slower and finer-grained photographic emulsions. These, in turn, give full scope to improvement in lens resolving power, and the resulting photography is easily capable of useable enlargement to nine or ten diameters.

The Aviogon lens, by Wild of Switzerland, offers mean radial distortion not exceeding 10 microns; the Pleogon, by Zeiss, specifies a mean distortion of less than half this amount: whereas an earlier lens, such as the Ross Wide-angle, produced distortion of up to 160 microns. Clearly, tolerances throughout the photographic operation had to be changed.

Film distortion, for example, needed particular attention. Even under tropical extremes of humidity and temperature modern plastic bases, developed during the past few years, exhibit differential distortions of less than 0·03 per cent and are now additionally treated to reduce the risk of static discharges during flight (an unfortunately common phenomenon over desert regions of exceptionally low humidity).

Similarly, the distortions introduced by flexing of camera compartment windows can exceed those of the lens itself, and windows are now frequently removed for most precise work.

Finally, flatness of film at the instant of exposure is now more than ever vital. Serious errors in subsequent contouring can arise from oversight in this respect and the problem is accentuated by the fact that there is no simple field check available to the operator. When the cost of re-positioning an expedition, once withdrawn, would be near prohibitive, the importance of high standards of camera maintenance, inspection, and operation, is evident. Most British cameras use a mechanical system for film flattening, a "langite" pressure pad and an optically flat register glass forming the two surfaces. Others, including all those offering the new lens performance, use vacuum to pull the film against a metal surface which is flat to within 0·015 mm. and which is placed accurately in the focal plane by machined surfaces on the lens cone (Figs. 2 and 3).

So much for the new lens and the repercussions of its introduction. Having obtained marked improvements in the quality of the photographic image, it is important

FIGURE 2. Williamson Eagle IX Aerial Camera showing (*a*) the pressure plate, forming part of the magazine and (*b*) the optically flat register glass.

FIGURE 3. Wild RC5A Aerial Camera showing the magazine pressure plate, with grooves through which air suction holds the film flat during exposure.

that nothing be lost when paper prints are made. Electronic methods of print shading have come into general use during the past two years. A point source of light scans the negative, its intensity being changed in inverse proportion to the density of the negative under exposure at any moment. Thus the highlights of deserts, river beds or shorelines, being dense on the negative, receive more exposure to bring out maximum fine detail recorded by the lens, while the thin portions of the same negative, representing perhaps forests and shadowy hill sides, receive restricted exposure and are correctly presented. The process is automatic, is only slightly slower than conventional printing from a fixed light source and, as a result, its advantages are available to field workers overseas.

Aircraft

Most survey aircraft used by civil operators over undeveloped areas overseas are adaptations of wartime or immediately post-war types. They include: —

	Speed (knots)	*Survey Ceiling (ft.)*
B17	160	33,000
Dakota	140	26,000
Mosquito	200	36,000
Dove	135	20,000
Lodestar	160	25,000
Survey Prince	140	23,000

None of these is entirely satisfactory: some are becoming uneconomic to operate on account of deteriorating spares availability, and although all can reach a survey ceiling of 20,000 ft. (in two cases with very limited endurance), only two can operate at altitudes in excess of 30,000 ft. Only one, the Survey Prince, has been designed specifically for survey.

Surveys over remote areas require an unusual combination of aircraft characteristics. An operating ceiling of at least 30,000 ft., a minimum payload, with full tanks, of 1,700 lb. and a maximum of 5,000 lb., and a minimum range of 1,700 n. miles—to these essentials we add a configuration which allows both pilot and co-pilot good forward and vertically downward visibility.

Ceiling is dictated by the improved lenses now available and the resultant decrease in photographic scales; minimum and maximum payloads by the weights of operational survey equipment and total expedition transport, while a reasonably high speed is necessary to take advantage of short spells of good weather.

Above all, the aircraft must be cheap to operate. Like most aerial work aircraft problems, this one also turns on cost and reflects what H.R.H. The Duke of Edinburgh referred to as the "ever-widening gap" which invention and development have opened up between aerial work in the outback and civil airline operation on the main routes of the world. Most modern civil aircraft capable of meeting the above requirements, such as the Dart Herald, Fokker Friendship, and in a different category, the Lockheed Jetstar, are as yet too expensive to buy (although not necessarily to operate) for air survey. Equally, the civil air survey market, up to the present, has been too small to warrant the design and manufacture of a type to meet only its own requirements.

Service aircraft present a different picture, because existing P.R. or transport aircraft can be readily converted for aerial survey, as and when required. The English Electric Canberra, for instance, has been used successfully by the R.A.F. since 1955 on vertical photography for mapping purposes in Aden Protectorate, Northern Kenya, and in the Far East. In Canada, the R.C.A.F. use Lancasters both for photography and for Hiran surveys, while the U.S.A.F. have recently modified their Lockheed C130 turbo-prop transport for aerial photography and other forms of air survey.

Navigation

Accurate navigation, particularly in the local sense of flying exactly parallel tracks, is essential to air survey and has presented its own problems in remote areas where detail is sparse. Surprisingly, navigational methods have remained at a comparatively low level of development, as compared with the perfecting of technique which has occurred in photography and photogrammetric plotting.

82 Squadron R.A.F., in Lancaster aircraft, used radar methods during their African Colonial surveys, flying circular flight paths on pre-computed radii from ground repeater stations. The latter were established and manned by small detachments and the system worked satisfactorily under Service conditions. The high cost of maintenance of ground parties and equipment, usually on hill tops in remote areas, and the time required for installation, cannot be justified commercially. Moreover, significant photogrammetric problems arise when circular photographic strips, near to the ground station and consequently of small radius, are used for mapping (Fig. 4).

Since 1953, photography in the Colonies has been handled by civil contract and navigational methods have been entirely visual, using straight flight lines. A simple side sight is used (Fig. 5) by which the median line of lateral overlap between adjacent photographic strips can be established from the air and recorded either on existing photography or, in more sophisticated systems, by hand sketching of well defined points of ground detail from the cockpit. These serve to position adjacent strips flown in the reverse direction, securing correct lateral overlap. The method requires neither control nor tie strips and can be practised more efficiently in undeveloped areas of sparse detail than in others where an over-abundance of detail may be confusing. It requires skill, training and something of a gift for the job—it is also inexpensive, reliable, and needs no ground organisation.

Completely airborne aids to navigation will usually be preferable in surveys of remote areas, all other advantages being equal, and the recent appearance of Doppler on the civil market has provoked an interested response from air survey operators. The applications of Doppler to air survey have not yet been fully assessed. An accurate drift angle, combined with a heading reference of comparable accuracy, will assist in the

flying of parallel tracks. This application of Doppler is likely to be more significant in very low altitude geophysical prospecting surveys at close flight spacings, than in high altitude photographic surveys. Until now, the former have required maps or small scale photography, both as an aid to navigation and as a base on which to plot results. Maps being generally non-existent in undeveloped areas, photography has had to be undertaken, with consequent risk of delay. Doppler allows the geophysical survey to begin immediately, and if profile locations are recorded either graphically (as in a Decca Flight Log) or by automatic registration of x and y co-ordinates, selected areas of interest may be revisited, again using Doppler, for aerial photography and more detailed geophysical measurements.

Photographic surveys in cloudy weather areas might be expedited by the use of Doppler, used as an aid to locating gaps in existing cover. Similarly, when photographing featureless desert areas defined in extent only by geographical co-ordinates, it is sometimes difficult to establish boundaries and excess photography is undertaken as an insurance. Doppler could avoid this waste. Doppler will also measure ground distances to an accuracy of one or two parts in 1,000 and might be applied to obtaining the scale of aerial photography. In very remote areas, such as Antarctica, it could be used to develop a rough ground trilateration system, simply by flying over the side lengths to be measured.

Some Applications of the Photograph

Air survey, through the aerial photograph, facilitates a first-stage low cost reconnaissance survey before rigorous mapping is undertaken. Indeed, the majority of aerial photographic programmes are neither requisitioned nor paid for by map producing agencies. They are more frequently ordered by engineers, geologists, or foresters, working in the field, whose requirements do not immediately justify the preparation of an accurate map. The photographs, or a mosaic compiled therefrom, are adequate and can be prepared within weeks from completion of flying, whereas maps would require months or even years. The Island of Barbados, for example, was photographed by a British civil operator in January 1951, and a mosaic of the island (Fig. 6) was available in Barbados within ten weeks.

The photograph is not only available more quickly —it contains more detail than a conventional map.

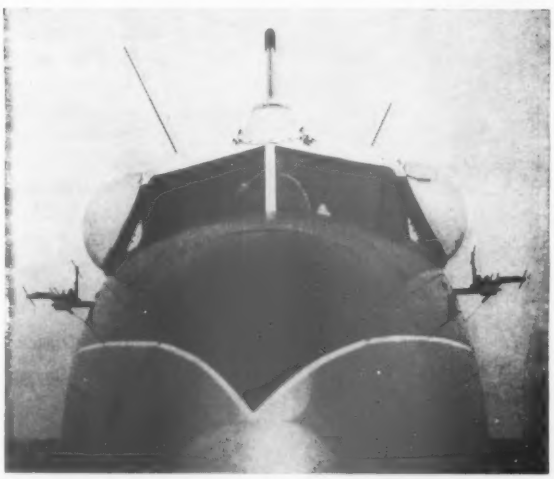


FIGURE 5 (*above*). Photographic survey D.H. Dove, showing side sights for navigation of parallel strips. The three lower aiming wires, reading from innermost outwards, give (*i*) median line of lateral overlap (*ii*) outside limit of photographic cover (*iii*) far edge of adjacent photographic strip.

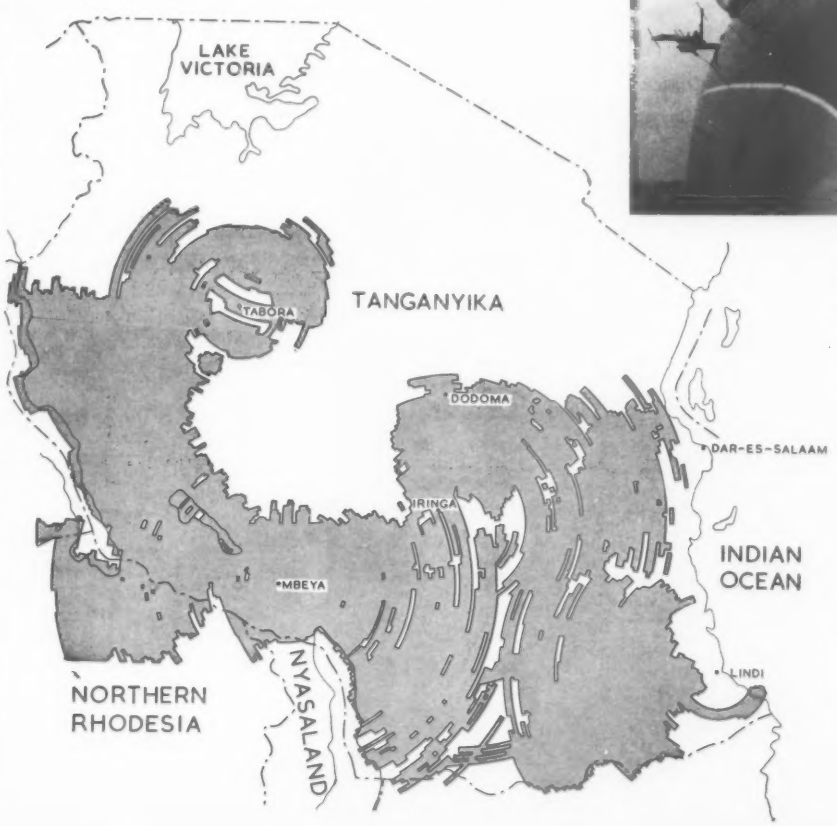


FIGURE 4. (*left*). Photographic cover achieved by the R.A.F. in Tanganyika, using radar control stations at Mbeya, Iringa, Lindi and Tabora. (*Based upon a diagram prepared by the Department of Lands and Surveys, Dar-es-Salaam*).

This could be a disadvantage in, say, Europe, but not in undeveloped territories, where conventional map detail is sparse. A geologist, for example, working across the Buhoro Flats of Southern Tanganyika, could easily establish his position by reference to local vegetation pattern on the photograph, whereas a map of the same area, necessarily generalised and containing only certain topographical features, would leave him without recognisable landmarks. To quote from a recent publication of the Food and Agricultural Organization of the United Nations: "With few exceptions, the most useful field maps are aerial photographs, which should be regarded as essential prerequisites for practically all surveys," or again, from the West Indies: "In the absence of suitable topographic and geological maps of St. Vincent, the field work . . . consisted of ground traverses predetermined from careful study of aerial photographs." The technical expert no longer needs to wait for maps or to make them himself before beginning work.

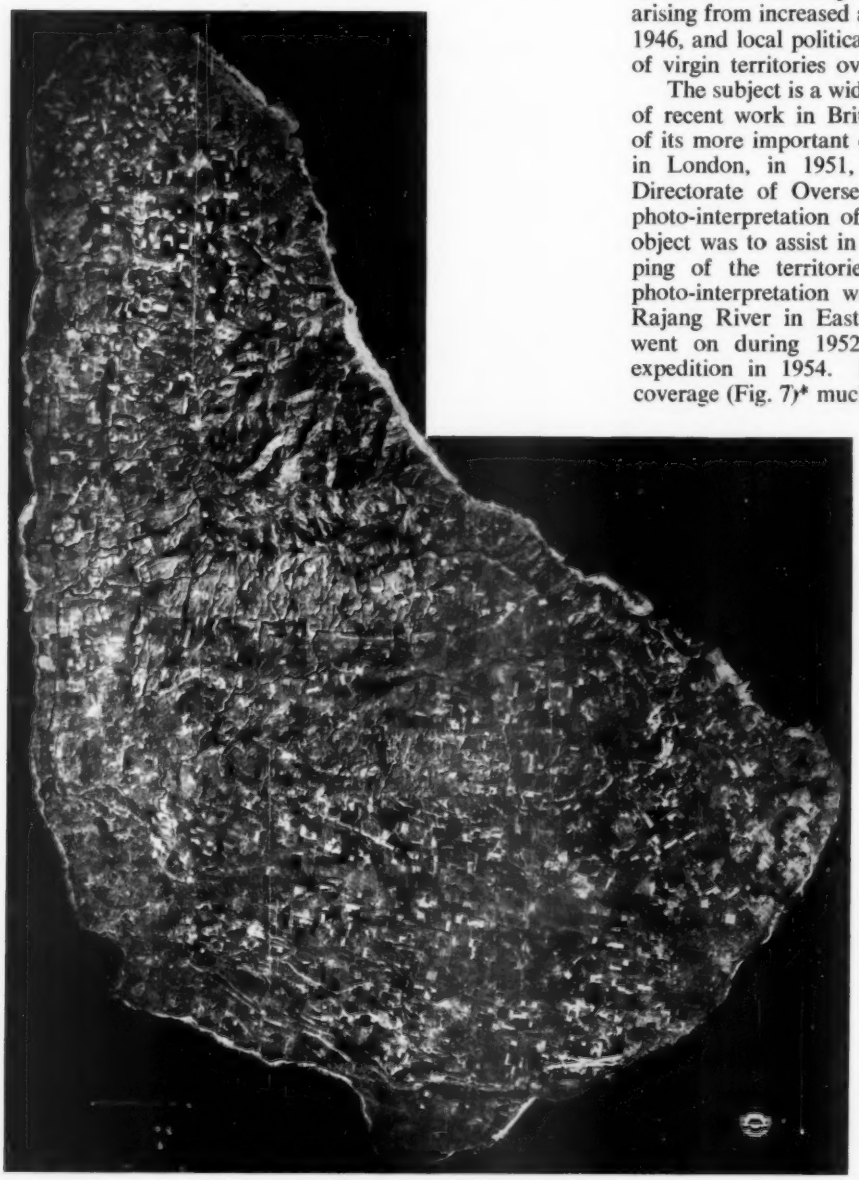


FIGURE 6. Photographic mosaic of Barbados. The original assembly involved 275 separate photographs.
(Photograph by Fairey Air Surveys Ltd.)

GEOLOGY

Geologists, in particular, have obtained valuable assistance from aerial photography, not only in its simple role as a field-map, but from other more specialist information which can be interpreted from it. Photogeology is not, of course, a recent development. Much of the aerial photography done during the thirties, as for example the KLM survey of New Guinea, had a geological objective. Progress is to be noted principally in the much more general application of the method arising from increased availability of aerial surveys since 1946, and local political pressure for rapid development of virgin territories overseas.

The subject is a wide one, and the following example of recent work in British Borneo may illustrate some of its more important characteristics. The work began in London, in 1951, when Mr. G. Whittle of the Directorate of Overseas Geological Surveys began a photo-interpretation of existing R.A.F. coverage. His object was to assist in the direction of geological mapping of the territories. Among areas selected for photo-interpretation was the unexplored basin of the Rajang River in Eastern Sarawak and work on this went on during 1952-53 in preparation for a field expedition in 1954. Despite the general high forest coverage (Fig. 7)* much hitherto unsuspected geological information was obtained. It was established, for example, that there are three main rock groups within the area. In addition to a sedimentary series of rocks (forming the Batu Bora Range), there are extensive plateau areas of volcanic origin and it was established that these are younger, geologically speaking, than the sedimentaries on which they rest.

All of this information was derived before a single traverse was started in the field, but even more important, "through the recognition of these major lithological groupings, their structure and relationship, as well as their probable extent, it was then

**See* p. 8.

possible to select in advance areas for geological field investigation *knowing full well that the optimum of geological results was likely to be achieved for a minimum of field effort*" (italics by present author).

Herein lies the principal advantage of photo-geological methods, of tremendous economic significance. Whittle continues, "Without the prior assistance of this regional photo-geological study many seasons of field work could well have elapsed before the key nature of the Batu Bora Range in the regional geology of Eastern Sarawak became evident. Without prior knowledge of the geology of this range, derived from a stereoscopic examination of the air photographic cover, a visual air reconnaissance *per se* is likely to be far less repaying in its geological results: as witness the August 1952 visual air reconnaissance party which traversed the Usua Apau plateau from North to South and which failed to observe the full geological implications of this watershed area"[15].

(Companies concerned with oil and other forms of mineral exploration are alive to this property of aerial photography, which permits a rapid sub-division of very large areas into those of potential geological interest. Using air survey, they are able more easily to comply with the type of condition frequently attached to exploration concessions in newly developing territories by which large proportions of the concessional area must be surrendered within a given period.)

In 1954, Whittle went into the field with the objects of checking the general validity of his photographic interpretation and of studying in detail two key areas in the Rajang Basin which had been selected on the photography and from which confirmation was required on the structure, age relationships, and lithology of the main formations. The detail of his geological work is beyond the scope of this paper, but it is of interest to note the basic usefulness of the aerial photograph as a field map. Whittle used it to plan his programme, to predetermine dropping zones for food supply, and to select access routes which would avoid topographical obstacles.

Figure 8 shows how his overland route from the limit of canoe navigation on the Danum River was chosen from photography to circumvent the dangerous and impassable rapids on the lower Plieran River, rejoining the latter above the rapids where canoe transport could again be used. Note also, from a geological point of view, how the ridges of sandstone crossing the river give rise to rapids which alternate with troughs of shale along which the river flows easily and which are readily eroded out into prominent lagoons. The Danum River, flowing over a wide band of shale, is free to pursue a meandering course without obstruction.

This survey in Sarawak is only one example among many of comparable interest in newly developing territories. Not all are of immediate economic value; some, such as the geomorphological analysis of sand dunes in Northern Nigeria, made by Dr. A. T. Grove, are of long-term scientific interest. The photograph illustrated in Fig. 9* is fast becoming a classic, so clearly does it demonstrate how a regional pattern (in this case of sand dunes alternating with impermeable and badly drained bedrock, swept clear of sand) can be appreciated on the aerial photograph. The outlines of the dunes "have been modified by erosion, and they are well covered by woodland in many areas so that it is difficult for an observer on the ground to appreciate their arrangement. From the air, however, the dune patterns are clear and they are strikingly apparent on blocks of air photographs"[5].

In some areas, such as bush-covered peneplains, photo-geological interpretation is of little value and recourse must be made to a much newer group of air survey techniques which measure the physical properties of radio-activity, conductivity, and magnetism as aids to exploration.

AGRICULTURE

Not less than geologists, agricultural experts now make day-to-day routine use of aerial photographs. It is well that this aid should be available to them, for 40 per cent of the world's population is undernourished, the population itself is increasing by 60,000,000 per year, and the agriculturist's task is a formidable one. Sound land-use plans must be the foundation of all measures taken to overcome bad farming practices which have arisen from ignorance of soil conservation

(Crown Copyright Reserved—Photograph by Royal Air Force)

FIGURE 8. Junction of Plieran and Danum rivers, Eastern Sarawak. Arrows indicate rapids where the river traverses resistant sandstone ridges.

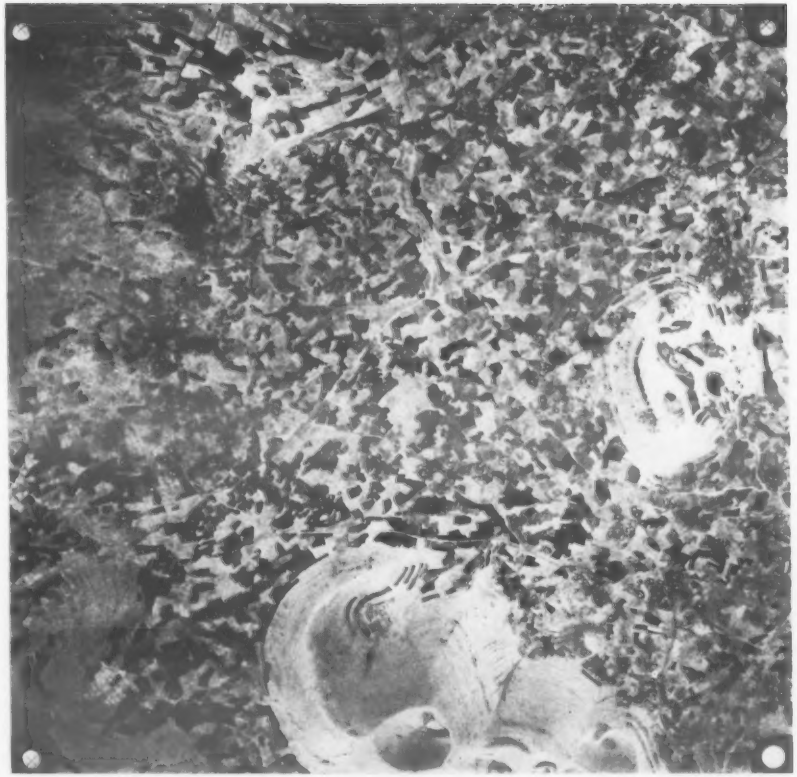
*See p. 8.

(Crown Copyright Reserved—Photograph by Royal Air Force)

FIGURE 9. Ancient sand dunes north east of Enugu, Nigeria.

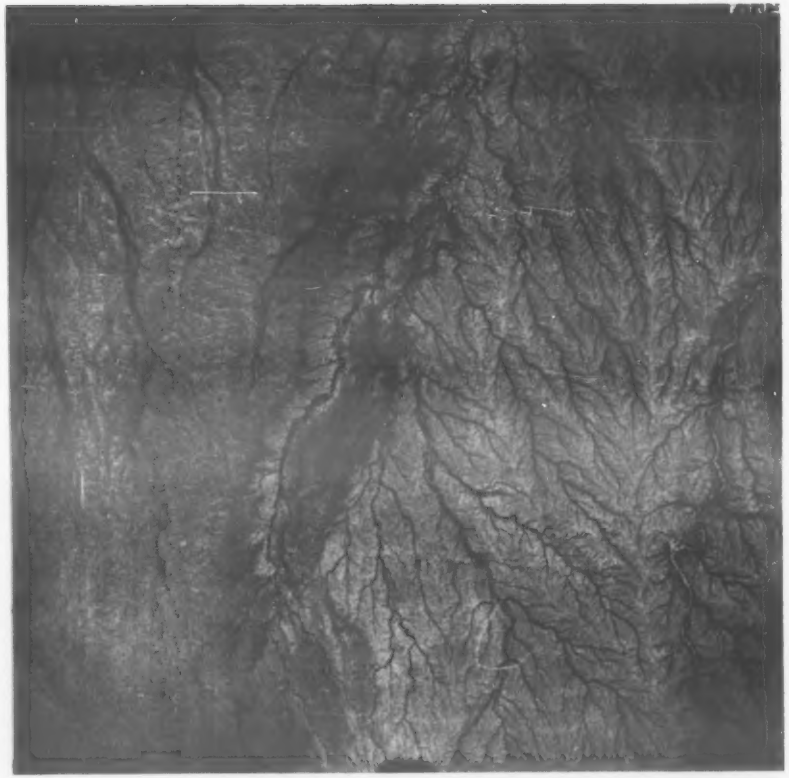
(Crown Copyright Reserved—Photograph by Royal Air Force)

FIGURE 7. Batu Song Mountain, Eastern Sarawak. A dissected sandstone pile, easily recognisable despite heavy forest cover.



(Copyright Government of Uganda—Photograph by Fairey Air Surveys Ltd.)

FIGURE 10. Extreme fragmentation of agricultural land near Kisoro, S.W. Uganda.



(Crown Copyright Reserved—Photograph by Royal Air Force)

FIGURE 12. Turkana Desert, Uganda. On the left an area of chestnut sand sheet, and on the right a heavily dissected stone mantle area. Note how the soil boundary is associated with difference in drainage pattern and vegetation.

requirements and, in some areas, from the centuries old tribal custom of excessive fragmentation by inheritance.

The 1954 Report of the Rhodesian National Resources Board contained these words, "The time for plain speaking has now arrived and it is no exaggeration to say that at the moment we are heading for disaster. We have on the one hand a rapid increase taking place in the African population and on the other a rapid deterioration of the very land on which these people depend for their existence and upon which so much of the future prosperity of the country depends"[12].

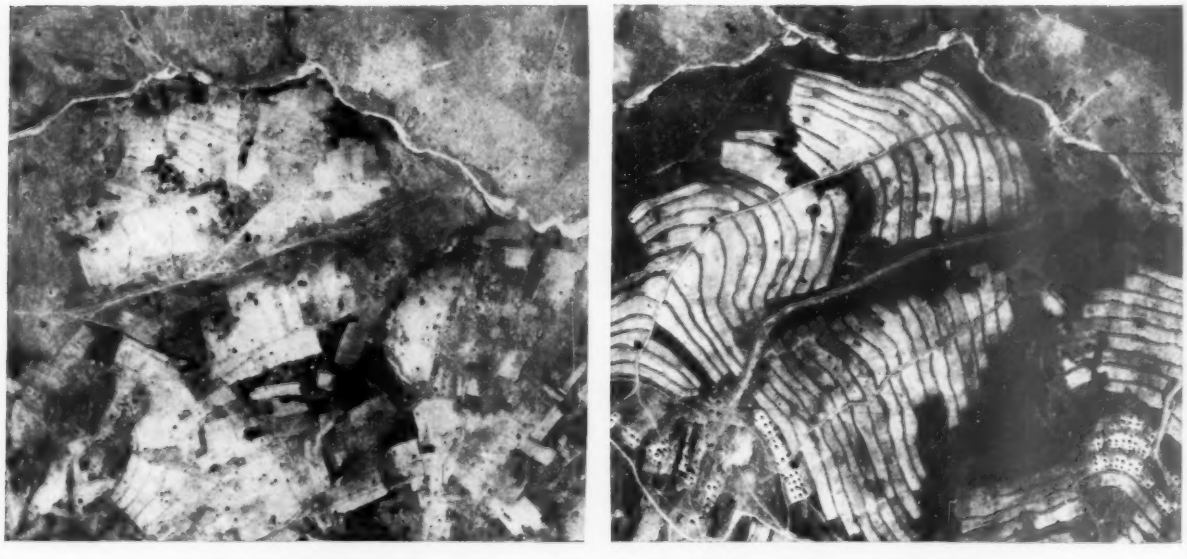
These words could be applied equally well to many other places. The problem is primarily an agricultural and a political one, but we shall see in two examples how air survey, in the form of aerial photography, is being used to help.

Take a typical small project in progress at the present time. In the Kisoro area of south-west Uganda, bordering on the Belgian Congo, pressure of population on land has resulted in extreme fragmentation of properties (Fig. 10, Kisoro), some parcels of land now measuring no more than twenty feet square. Improved farming methods, leading to increased food production, cannot be introduced while this continues, so families are moving voluntarily to an uninhabited area at Kihihi, 70 miles to the north, where government officers are using simple maps made from R.A.F. photography, to lay out new homesteads. Here incoming families are helped to fence their land and plan their crops. A year ago, buffalo roamed in their numbers over this country. In two years' time, resettlement completed and farms established, the area will be photographed afresh, and air survey used to record the boundaries of newly enclosed African-owned properties.

Farther south, in Southern Rhodesia, the Land Husbandry Act seeks to improve African agriculture and conservation and to introduce stability of tenure. A statement of steps required for its implementation *begins* with the words: "The first step in the implementation of the Native Land Husbandry Act is aerial photography."

All African reserves were photographed in 1955-6 at a scale of 1 : 20,000 to provide the basis for resettlement. This includes land classification, using photography, followed by the planning of conservation measures, the correct alignment of roads, and general provision for erosion control. Farming and grazing rights are assessed and allocated, marked by grass strips or low stone walls, and finally re-photographed from the air to record results. Figures 11(*a*) and (*b*) show photography taken in 1947 and 1954 respectively. Re-allocation and protection of land in the later photograph has largely replaced the scattered and haphazard cultivation of 1947.

At regional level, there has been important progress in the use of aerial photography to produce "land capability maps." These combine information on present land use, as interpreted from the photograph, with physical data such as soil types, drainage etc., obtained by photo-analytical methods. Soils are not identifiable directly from the photograph and the method used is to classify indicator features rather than soil profiles themselves. The six principal factors having a bearing upon soil character are climate, parent material, relief, vegetation, time and Man, and the external land surface characteristics to which they give rise are the elements on which the air photographic classification mapping is based. For example, a parent material of granitic resistant basement will result in narrow drainage lines, frequently rectangular in pattern, while superficial deposits themselves may be directly distinguishable by the drainage pattern which they induce. A now well known example has been noted by



(*a*) 1947. Irregular cultivation. (*b*) 1954. Showing the effect of soil conservation.

FIGURE 11. The Chinyika Reserve, Southern Rhodesia.

C. F. Hemming and C. G. Trapnell in the Turkana district of N.W. Kenya (Fig. 12, *see* p. 9).

Classification by landscape features results in a base map which can be readily transformed into a soil or land capability map by field sampling of key areas.

In 1958, Martin Brunt, Land Use Officer at the Directorate of Overseas Surveys, conducted a Land Use Survey in the Gambia, to determine suspected alterations in the areas of rice cultivation; the upland rice areas were said to have decreased, while simultaneously the area of swamp rice had increased. Aerial photography provided all the information required in a permanent and readily accessible form, the only field work being to check the initial photographic interpretation. Using air photography taken in 1946 and 1956 an historic comparison of the areas of rice cultivation was made. The area limits were plotted on a special series of maps; eleven other categories of cultivation and natural vegetation were also plotted from the 1956 photography. Brunt points out that certain natural vegetation categories have agricultural significance and gives as an example the correlation of mangrove with potential rice growing areas. The low mangrove areas are broadly those of soils suitable for rice growing if the land is to be empoldered, whereas high mangrove largely coincides with soils which are only suitable for swamp rice cultivation. It is thus of some practical importance that the two types of mangrove are distinguishable by stereoscopic examination of the aerial photography.

FORESTRY

Air survey has always been closely connected with forestry[1]. Since 1946, forestry departments of underdeveloped territories have benefited from large governmental programmes undertaken for general use, and although scales and photographic quality initially left much to be desired, the situation changed appreciably with the introduction of the Aviogon-type lens. Thus, R. G. Miller[8], writing on the use of air survey in British Colonies says, "the more recent photography has been much more consistent in quality, and has made it practicable to use enlarged prints to overcome the restrictions of the small contact scale in interpretation work."

Little photography in the dependent territories has been flown specially for forestry purposes: hence, perhaps, the comparatively small amount of work on measurements of crown diameters from large scale photographs as done elsewhere, seeking to relate crown sizes and tree heights to girth and timber volume. (In addition, it may be noted that thick undergrowth, common in the Tropics, and scarcity of gaps in the high tree canopy through which measurements can be taken, have also limited the use of air survey in this respect.) But much use has been made of the smaller scale cover for reconnaissance of forest resources, as in Northern Rhodesia, and for stock-mapping of gazetted reserves.

As in soil and land-use survey, so in forestry, the photo-interpreter's work needs to be supplemented by ground sampling, and the development of rapid sampling techniques has been a feature of post-war progress. The photograph can help by indicating routes for ground traverse likely to yield most useful information. In some cases, the broad undisturbed appearance of the canopy can lead to identification of species, without the examination of individual crowns which only large scale photography would permit.

In North Borneo[4] a system for mapping the vegetation of the whole colony has been described by Francis and Wood. Their method uses only photographic evidence and the classification is not by species but by topographic site and the average size of visible crowns. Areas of commercially valuable forests are apparent from this survey and can be measured. In Fiji, photography at scales 1/40,000 and 1/16,000 has been used for similar mapping, on the basis of canopy density, to ascertain the amount of unworked timber remaining.

Foresters have always shown particular interest in the use of infra-red and colour photographic emulsions. The former has the striking characteristic of a very light rendering of green vegetation, due to a much higher reflectance density in the infra-red than in any part of the visible spectrum. Yet coniferous trees, as a result perhaps of their needle-shaped "leaves," appear dark and foresters have taken advantage of this fact, when working in temperate latitudes, to distinguish coniferous from deciduous stands.

Colour photography in forestry, as in other fields, has a glamour attached to it which is not always justified by results. Much research is needed, both by photographer and interpreter, the yardstick in both cases being to achieve something which is not only more attractive in appearance than panchromatic but which can also be relied upon to contain additional information.

Air Survey as Applied to Mapping

Useful as photographs or photomosaics may be, they are neither easily reproducible nor do they depict topographical detail in the conventional and easily recognisable forms to which most map users are accustomed. But more important still, they suffer from two basic disadvantages:—

(*i*) The scale of a photograph cannot easily be determined with complete accuracy, even over flat ground, and local variations in scale occur whenever ground relief is present.

(*ii*) Although a pair of photographs viewed stereoscopically will give an impression of relief, which cannot be obtained in any other way, neither heights nor contours can be read directly.

These limitations can be overcome by combining the perspective views of overlapping aerial photographs into a true projection to form a map. This can be done in a variety of ways, from the approximate methods used for reconnaissance mapping to rigorous solutions involving complicated and expensive stereoscopic restitution instruments. Progress in plotting methods

has resulted from, and has accompanied, advances in camera and lens design already noted (Fig. 13), but a detailed assessment of development in photogrammetric equipment would be beyond the scope of this paper. Instead it may be of interest to consider some applications of aerial mapping overseas, and in so doing to illustrate the wide range of requirements and of solutions available.

Immediately after the war a survey was made of the Volta River Basin in Ghana, where the juxtaposition of bauxite ore and hydro-electric potential were under investigation. 82 Squadron R.A.F. provided K17 photography at scale 1 : 30,000. Maps at scales of 1 : 50,000 were prepared for the river basin and at 1 : 5,000 scale for the dam site at Ajena and the river delta at Ada.

The need for such contoured mapping was demonstrated by the fact that not until levelling parties went into the field was it known whether the proposed height for the dam at Ajena would result in flooding of the Volta River into French territory some 200 miles away.

Simple survey methods were used, with a measure of aerial triangulation by the slotted template system (Fig. 14). By this means, one fixed point on the ground serves to establish the absolute position of the centres of many aerial photographs, each of which is represented in the system by a sheet of acetate of comparable size. Each acetate template contains slots cut from the centre in the directions of photo detail common to adjacent exposures. They are linked together, relying on the assumption that whereas exactly vertical photographs are angle-true with respect to the plumb point (or the photo-image of the point vertically beneath the aircraft), this is also very nearly true for the general case of a slightly tilted photograph when ground relief is small in relation to aircraft height.

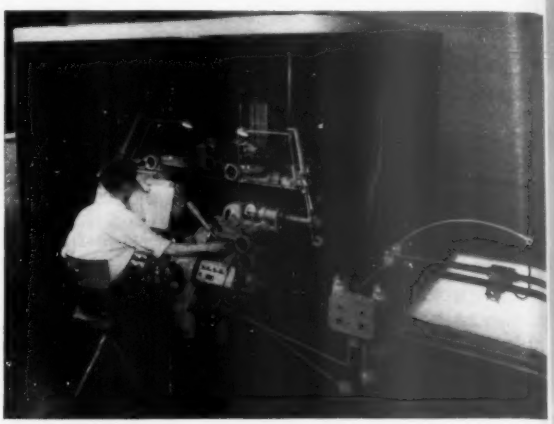


FIGURE 13. A first-order plotting machine, the Zeiss Stereoplanigraph C8.

Despite the use of this aid, the ground framework control for the Volta River area, of approximately 9,000 square miles, occupied six field surveyors for two years. Like many surveyors before them they suffered delays on account of sickness, poor communications, and the tropical rainy season which transformed sections of the basin from a network of interlacing streams and well worn paths into stretches of water twenty miles wide, impassable and devoid of recognisable landmarks.

Compare the Volta project with a survey made some eight years later by a British commercial survey organisation, in connection with the Kariba hydro-electric project on the Zambesi River. The main project involved photography of some 11,500 square miles at a scale of 1:44,000 which was completed in 132 flying hours, spread over a period of five weeks. The aircraft used was a Douglas DC-3 (Pratt and Whitney 1830/90c engines).

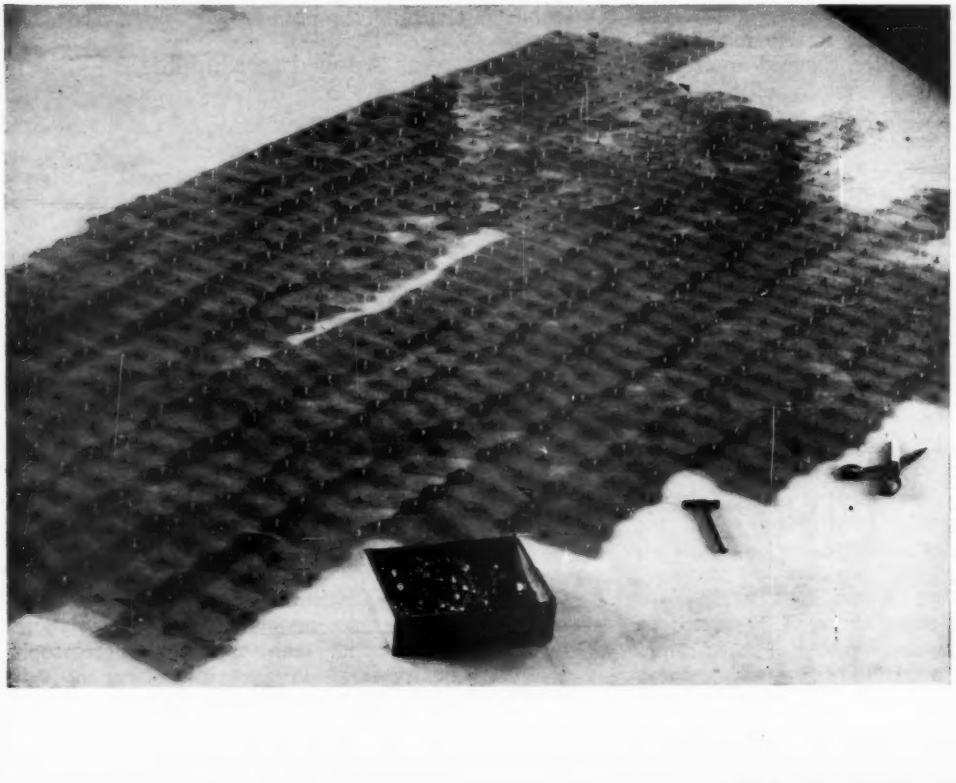
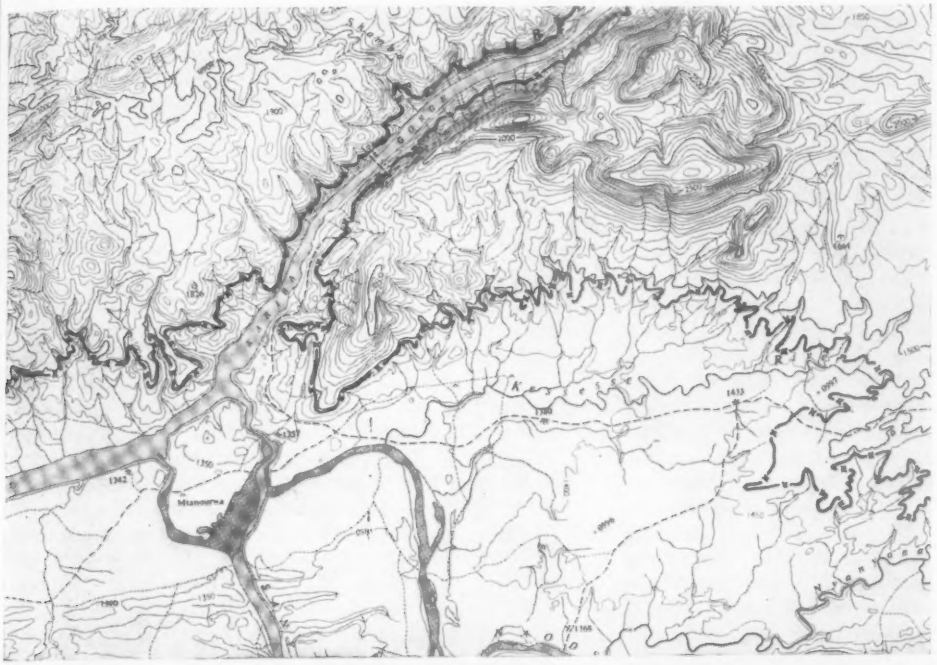


FIGURE 14. A portion of a slotted template assembly.



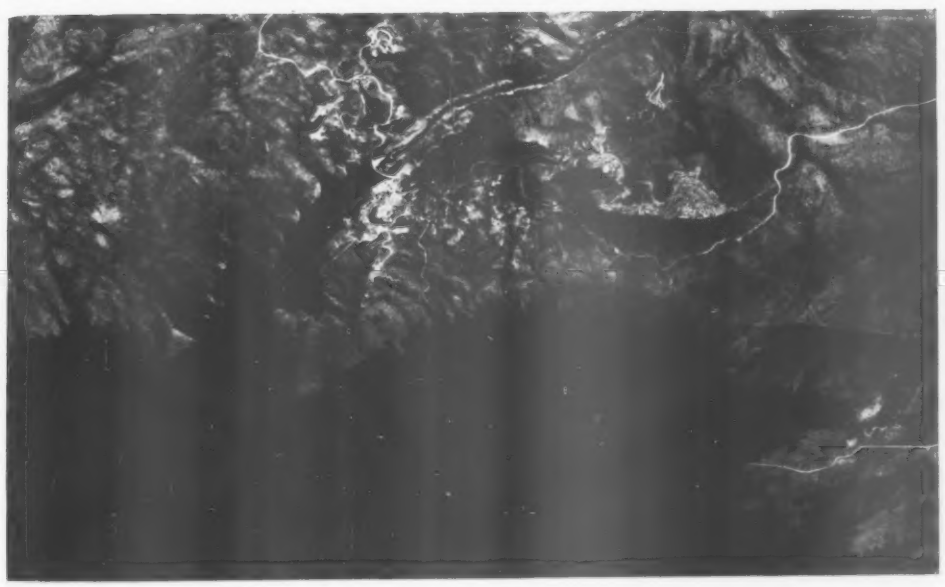


FIGURE 15.

(*a*) Contoured mapping prepared from aerial photography for the Kariba Hydro-electric Scheme on the Zambesi River, Central Africa, in 1955.

(*b*) Later photography taken in July 1959, showing flooding of the basin at that time. Note the close agreement between the 1475 ft. contour (taken from 1/25,000 scale mapping) and the water line on the later photograph.

(*Mapping and photography by Fairey Air Surveys of Rhodesia Ltd.; mapping copyright of Federal Director of Surveys, Salisbury, Southern Rhodesia; photography copyright of Federal Power Board.*)

The surveyors in the field again encountered many difficulties: haze restricted observations, brachstygia bush prevented movement of vehicles, rhino and elephant were in abundance as also were tsetse fly and Mopani bees, a small form of stingless bee which gathers in quantity around the eyes and any other moist and exposed parts of the body[3]. Nevertheless, efforts had been made to reduce the ground survey requirements. By flying special strips of photography from escarpment to escarpment across the bush-filled valley floor, fixed points established on the higher ground and identified on the photographic strips were used to carry values into the river basin itself. Some progress was being made, but field work remained the least predictable and most expensive part of the whole mapping operation.

The completed maps of the Zambesi survey carried 50 ft. contours and were used extensively by engineers in determining answers to such problems as anticipated reservoir capacity, extent of flooding towards the Victoria Falls, and location of possible points of overflow, according to the height finally adopted for the dam wall. Administrators used the maps to plan evacuation of those Africans whose homes would be inundated, contractors to prepare estimates for the

immense task of clearing forest from the coast line of the lake-to-be, and hydrographers to chart the floor of an inland sea some 2,000 square miles in extent (*see* Fig. 15, p. 13).

A further important application of aerial mapping in newly developing territories relates to cadastral survey, or the record of rights and title to land. A growing political consciousness among previously backward peoples has led in some areas to demands for individual title to land in place of existing customary tenures. In East Africa, a Royal Commission has considered the problem and has recommended that as customary tenures cannot satisfactorily meet the need for accelerated economic development nor the growing land shortage, they should be replaced by individual registered titles giving the holders greater security and enabling the land to become a negotiable asset which may be bought, sold, mortgaged or inherited[9]. One of the principal barriers to the implementation of such a policy would previously have been the utter inadequacy, in numbers, of ground surveyors capable of carrying out the demarcation and survey operations. Air survey meets the need. We have seen earlier how the photograph assists the agriculturist to plan the properties; at this point the surveyor enters the scene and, using only a framework of fixed points, is able to obtain from the photography a precise record of all boundaries adjudicated and established, a record which can be used subsequently to restore any boundaries destroyed, without risk of expensive and wasteful litigation.

In this context, progress in mapping by air survey methods is making an important contribution to social and political stability. Methods and problems naturally vary considerably: in sandy desert areas, for example, suitable only for low density cattle grazing, it may well be that property boundaries marked on a simple photograph would suffice, whereas in the land hungry regions of the Far East a boundary displacement of one foot could be important and all co-ordinates must therefore be measured rigorously, using the refinements of a first order plotting machine.

Large scale topographical mapping is required more frequently in newly developing territories than is generally supposed. In one year, 1958, in Sierra Leone, surveys at 1 : 2,500 scale were made by aerial methods of the township and environs of Freetown for municipal and town planning purposes, as well as of the mining area of Marampa some 52 miles away to the north east, surrounded by tropical forest and swamp, a total of 26,000 acres in all. The Marampa survey was ordered to replace existing mine plans which had become inaccurate and out of date. Photography was completed within six days from the decision to proceed, using a D.H. Dove survey aircraft. The maps include contours and these have been used for volumetric analysis of the principal exposed ore body, as well as for planning the exploitation of a smaller deposit to the south east. The accuracy of such contouring, using modern equipment, entirely belies the prophecies made when precise photogrammetry was yet in its infancy, "that contours plotted from air photographs cannot compete in accuracy with ground work"[6] (Fig. 16).

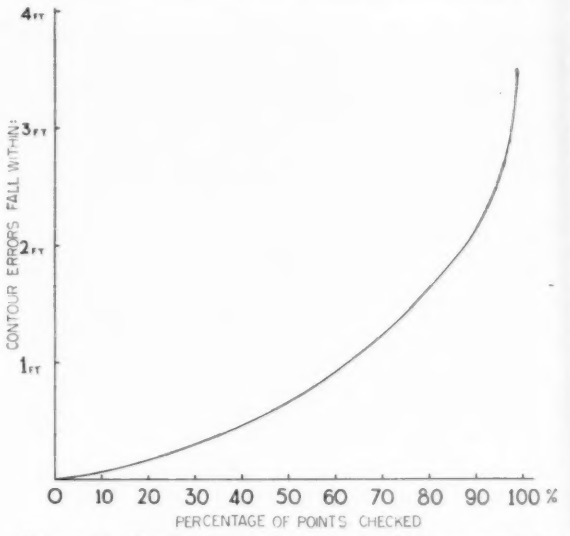


FIGURE 16. Graph of contour errors revealed by ground check of survey made from photography at 6,000 ft. altitude, near Nairobi, 1955.

Airborne Electronic Aids

The cost of ground framework surveys is an important factor in aerial mapping. We have already seen how aerial triangulation can effectively reduce the ground control required. This can also be done by measurements taken from the aircraft during flight and much progress in the development of such methods has been made during the past few years.

In the newly developing territory of Northern Canada a trilateration network of geodetic control points extending over an area of more than two million square miles has been surveyed by airborne Shoran and Hiran since 1949[10] (Fig. 17). Hiran, which is a more accurate form of Shoran and from which it is chiefly distinguished by the inclusion of a gain-riding technique to minimise measuring errors caused by variation in signal strength, is a pulse radar system operating in the V.H.F. band. Distances of up to 500 miles between survey aircraft and co-operating ground station can be measured in terms of time taken for the double transmission.

Trilateration is a framework of triangles which are surveyed by side lengths rather than by angular measures, as in triangulation. The technique is to fly the aircraft across the line to be measured, approximately midway between the terminal points. Slope distances are read continuously by Hiran to each of the two stations, and at the point of crossing the sum of these is at a minimum (Fig. 18). This minimum value is determined mathematically and, after correction for slope, can lead to a determination of the geodetic distance between the stations. The measurement of three such distances, between three ground stations, forms a triangle, and the operation can be repeated to build up a trilateration network with side lengths of about 200 miles.

In 1957, using Hiran, the consistency of results achieved in Canada was of the order of 15 ft. for this side length, or about 1/70,000. No other system, air

or ground, could possibly have provided control for topographic mapping over so large an area in so short a time. Its accuracy is entirely adequate for 1 : 250,000 mapping, but whether errors arising from the absence of independent azimuth control will limit its usefulness for any other purpose remains to be checked as surveys by classical methods are carried farther north. Proof of the value of the system is that it is likely to be many years before these checks can be made.

Following trilateration, one million square miles of photography have been completed in Northern Canada, of which 75 per cent include conventional Shoran fixes for all camera exposures. These are based upon ground stations of known co-ordinate already fixed by trilateration.

Some disadvantages of Shoran/Hiran trilateration methods for the establishment of control are to be found in the immense logistical effort required to transport and maintain ground stations, and in the need for peak efficiency of the delicate electronic equipment if adequate accuracy is to be achieved. The former can be appreciated from an American Hiran trilateration project planned along the north east coast of South America, passing through British Guiana and involving some 35 Hiran ground stations and 207 lines. A. M. Wilson, of the Air Photographic and Charting Service, U.S.A.F., estimates that this will need four Hiran-equipped aircraft, one cargo-carrying aircraft, two ocean-going vessels of LST size, with helicopters, and ground/amphibious transport according to conditions[14]. Such surveys can probably be justified for major connections between geodetic systems, but simpler and less expensive techniques may be more acceptable in most newly developing countries within the Commonwealth.

Much has been done to reduce dependence upon positions surveyed by ground methods, but ground heights present a more difficult problem. Such control is essential for contouring (the Zambesi project required some 4,400 miles of levelling), and while heights can of course be carried forward in the photogrammetric

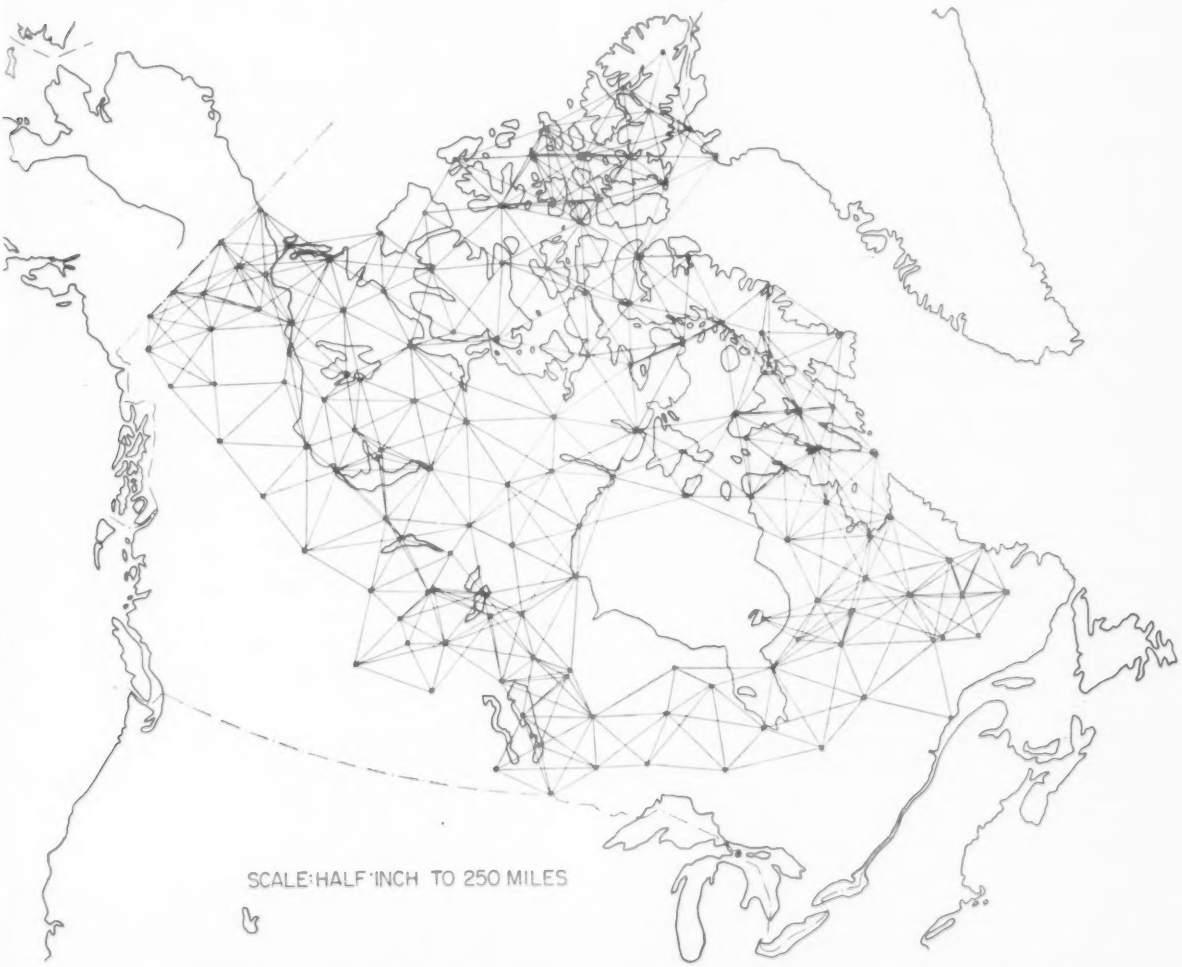


FIGURE 17. Airborne trilateration network surveyed in Northern Canada during years 1949 to 1958.
(Based on a map prepared by the Department of Mines and Technical Surveys, Ottawa.)

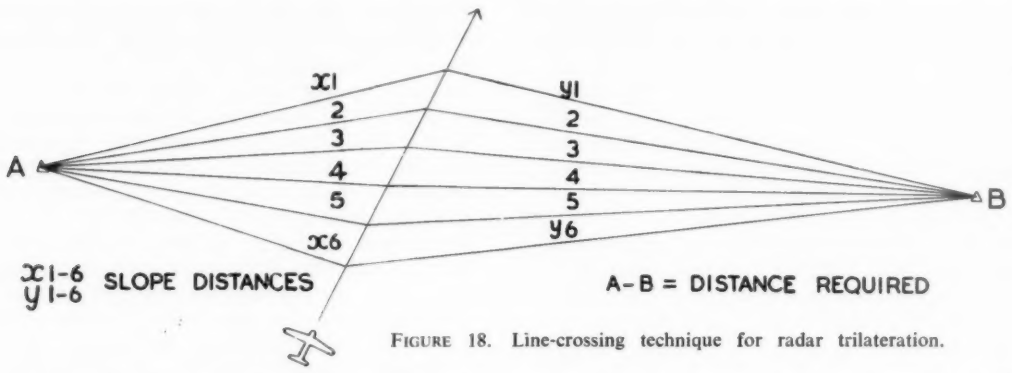


FIGURE 18. Line-crossing technique for radar trilateration.

plotting machines in much the same way as positions, the tolerances are more exacting and check points consequently more numerous. For these reasons, particular interest is now being taken in a device invented and developed in Canada, known as the Airborne Profile Recorder. This is really two instruments: a radar altimeter of 1° beam width using a 44 in. diameter reflector with which is aligned a spotting camera, and a hypsometer (Figs. 19 and 20). The former records distances from aircraft to ground surface; the latter gives a precise measure of small vertical movements of the aircraft continuously from the starting point of a flight. Algebraic additions of these two quantities, subtracted from the value obtained by flying over sea, will give heights of selected points along the aircraft's course with respect to the pressure surface obtaining during flight (Fig. 21). Inclination of the latter may be corrected by ground checks at the two ends of the strip, while undulations in the surface are revealed by changes in drift measurements.

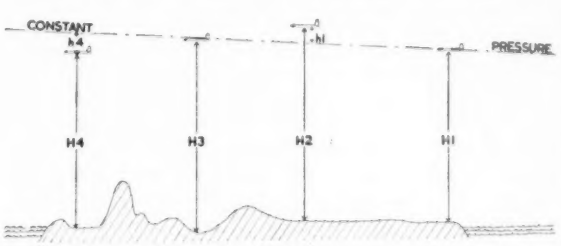
A grid of such profiles may be adjusted to form a homogeneous framework for use instead of ground control. This was done earlier this year in Aden Protectorate where profiles were flown over an area of 20,000 square miles, in the course of a mapping project ordered by the Director of Surveys, War Office. Only six ground heights were available, surveyed by barometric methods and of uncertain value, because of local thermal disturbances. On the other hand, the altitude of 16,000 ft. used for profiling had been selected from the Air Ministry Upper Air Charts for the past five years, and the maximum pressure gradient encountered was only 23 ft. in 160 miles. The results required no adjustment and the total profile length of 2,600 miles was completed by a long range DC-3 aircraft in eight weeks, involving 75 flying hours.

There are limitations to the method—uncertainty of reflectance over vegetation, the need for a level reference surface to be used in pre-flight instrument adjustment, and inadequate upper air measurements in the undeveloped parts of the world—but when combined with photogrammetric measurements quite remarkable accuracies can be achieved. In Canada tests have been made by the National Research Council (Department of Applied Physics) in which an accuracy of ± 8 ft. has been obtained from a profile flown at 20,000 ft., 200 miles long, with control only at each end. In Aden, a point in the desert 210 miles north west from Mukalla was heighted on two different sorties, several days apart, and by air routes differing completely as to location and direction of final approach. From a flying height of 15,000 ft. the difference in values was 18 ft.

The principal uncertainty is that of undulation in the constant pressure surface, which will naturally be directly reflected in profile errors. Work is now going on, in this country and Canada, to obtain a better appreciation of the connection between drift angle and pressure change, and one experiment recently completed used Doppler to measure drift more precisely than optical methods hitherto used.

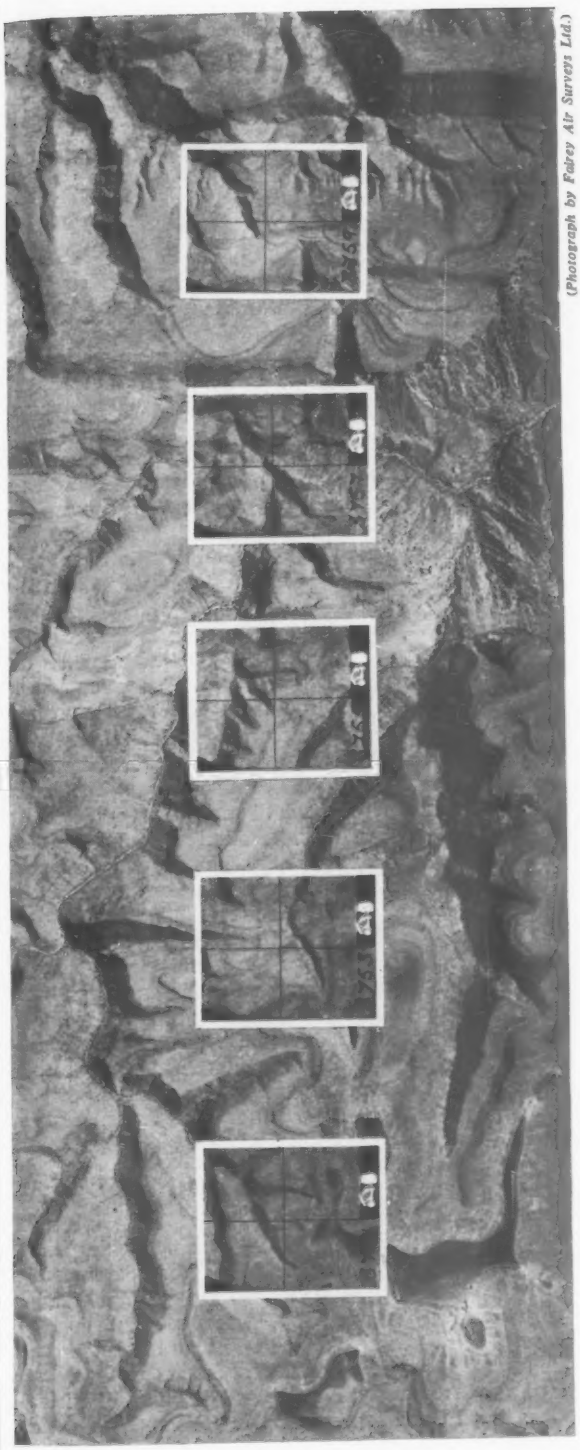
The Airborne Profile Recorder could be a major step forward. In Northern Canada, its country of origin and to whose vast areas of low relief and sparse vegetation it is so well suited, it is already in use. In other areas it may be found that a simple statoscope, measuring only differences of aircraft heights at instants of camera exposure could be more effective, used either independently or in conjunction with a gyro-stabilised or tilt-recording camera. In Finland changes in aircraft lateral tilt (an accurate knowledge of which could largely reduce the need for ground levels) are measured by simultaneous photography of port and starboard horizons, the two auxiliary cameras being accurately calibrated to the main vertical units, while in Italy a solar periscope enables both lateral and longitudinal orientation data to be obtained in flight from comparisons of changes in solar altitude and azimuth.

Complete independence from ground measurement, enjoyed by airborne systems such as those just described,



H1 – H4: ground clearances from radar altimeter.
h1 – h4 : deviation from the constant pressure surface (by hypsometer).

FIGURE 19. Airborne Profile Recorder flight.



(Photograph by Fairey Air Surveys Ltd.)

FIGURE 20 (*above*). A mosaic of aerial photographs on which are superimposed the 70 mm. "spotting" photographs used with the Airborne Profile Recorder.

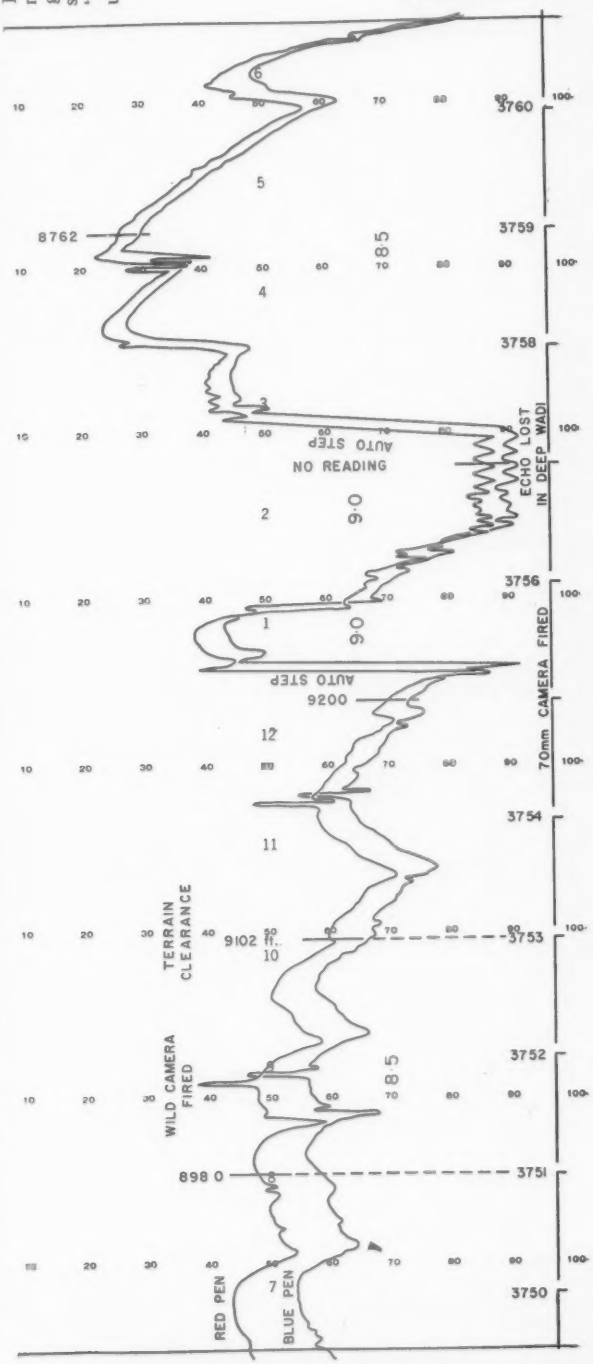


FIGURE 21 (*left*). The chart made by the APR, aligned with the strip of photographs in Figure 20.

is not an unmixed blessing. In major construction projects, for example, the engineer must sooner or later take measurements by classical methods, and at this point he would normally base his work on the framework of ground points which the airborne systems no longer provide. What advantage, it has been asked, can there be in a wholly airborne system of providing control for maps, if subsequent development will require ground framework in any case?

The invention of the Tellurometer in 1954 has affected thinking in this respect, and although the Tellurometer is still only a ground-based instrument, any review of progress in air survey in newly developing territories must take account of it. The Tellurometer measures the radio distance between two points by determining the time taken for a modulated continuous radio wave to make the double journey (Fig. 22). Accuracy of measurement is about 1/200,000 and lines of up to 35 miles in length can be measured in an observing time of less than 30 minutes per line, neither fog, light rain, cold, nor darkness having any effect upon accuracy. The equipment weighs about 134 lb., and costs £1,200 per station.

The increased ease with which ground points can be established by Tellurometer suggests still closer enquiry into the capital cost and maintenance effort required for such systems as Hiran. The result may be that Hiran will be used only over areas where even Tellurometer methods of ground survey are wholly impracticable. A difference in range characteristics should also be noted: Hiran optimum range is of the order of 200 miles, Tellurometer maximum effective range is 50 miles, with optimum at about 35 miles. The gap needs to be filled and the very recent development of an airborne Tellurometer system, known as Aerodist, attempts to do this.

FIGURE 22. The Tellurometer.

Aerodist sets out to provide control points either by the line crossing technique or by a method known as continuous trilateration. The manufacturers claim an accuracy of one part in 100,000 and suggest that with two line measurements, intersecting at a satisfactory angle, and a barometric height, the position of an aircraft can be determined at a range of approximately 100 miles from the base stations to an accuracy of better than 10 ft. The frequency of the continuous radio wave (1,200-1,400 mc./sec.) is much lower than for the ground Tellurometer system, largely as a result of the increased range requirement, although the desirability of using wide-beam aircraft aerials, with greater power requirement, also contributes.

Airborne Geophysical Survey

Geophysical survey has a history which extends back well beyond the invention of the aeroplane. In a letter written in 1640 the Swedish Chancellor Axel Oxelstierna made what is believed to be the first reference to the use of magnetic surveys in prospecting for iron ore, but it was not until three hundred years later that airborne magnetometers were used to detect enemy submarines during the Second World War. The science has broadened and expanded during the past ten years and the three physical properties of magnetism, radioactivity, and conductivity are now measured from the air both as a prospecting method leading directly to the location of mineral deposits and, as a means of obtaining regional geophysical information which assists in building up a picture of broad geological structure.

The simplest form of airborne geophysical survey—because all necessary equipment can be carried within a small aircraft—is a radiometric survey. The basic equipment consists of a scintillation counter (Fig. 23), radio altimeter, chart recorders, and a ground position referencing system such as a 70 mm. auxiliary camera. The scintillation counter comprises one or more crystals of sodium iodide, which has the valuable property of scintillation when bombarded by incident gamma rays. The scintillations are noted by means of a photomultiplier tube, optically coupled to the crystal and the total count integrated against the time constant selected. The efficiency of the scintillation counter is very much higher than that of the geiger counter and the application of aircraft to this type of work has been made possible by the fact that time constants as short as one second may now be used.

Aircraft height may not, in general, exceed 500 ft. and this ground clearance must be maintained within ± 20 per cent, variations from datum being recorded by a radio altimeter. The lateral spacing of flight lines is equally important, for even at quarter mile intervals a point source of an ore body with a radius of 60 ft. and located midway between flight lines, can only just be detected at 500 ft. altitude. Very small ore bodies can therefore be exceedingly difficult to isolate except where, as in the Tropics, weathering and leaching of surface rocks may disseminate radioactive minerals over a wide area, and provide a larger target.

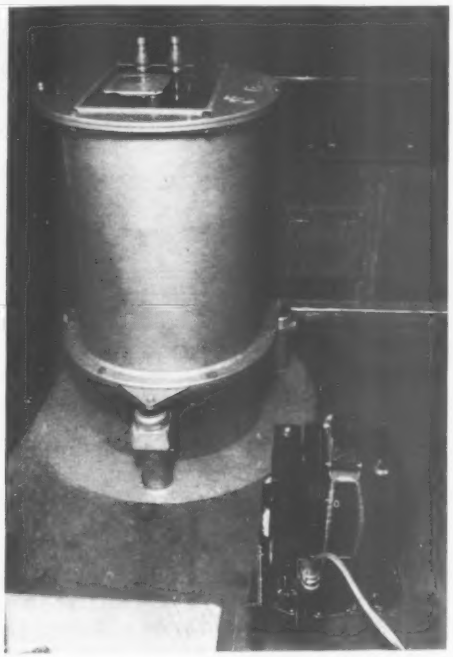


FIGURE 23. An airborne scintillation counter.

Sources of gamma radiation may be radium, thorium or potassium and important progress has been made in applying the spectrometry principle to the sorting of gamma energy. This is typified in the Mk. XI discriminating scintillometer manufactured by Nuclear Enterprises Ltd. of Winnipeg, Canada, by which radiations characteristic of radium and thorium may be discriminated from those of potassium, or alternatively radium indications from those of thorium. The significance of this development is emphasised by the presence of potassium in most igneous rocks.

While the primary purpose of radiometric surveys is to locate anomalies which may arise from radioactive deposits, the grouping of outcrops having the same radiation level can be a valuable guide to the basic geological mapping of undeveloped territories. The Canadian Government has achieved a fair amount of success in outlining geological contacts and strata changes from radiometric surveys of this type, principally in the Canadian Arctic Islands.

Magnetic methods of prospecting are based on variations in magnetic susceptibility of certain ores and rock formations from those of surrounding rock, resulting in local variations in the intensity of the earth's total magnetic field. The instrument most commonly used in newly developing territories has been the Gulf (total force) Magnetometer, developed by the Gulf Research and Development Company of U.S.A. This has a sensitivity of 5 gamma and can thus be used to detect not only major ore bodies but also the very small anomalies which result from variations in depth of slightly magnetic basement rocks. In this regional exploratory role the Gulf Magnetometer has been of special value in the initial study of geological structure in areas previously unmapped, and because of the close connection between basement topography and the sedimentary situations in which oil may be trapped, it has been used extensively by oil exploration companies.

The detector equipment itself is carried in a bomb-shaped, non-metallic, weatherproof "bird," towed at the end of a 150 ft. cable to isolate it from magnetic disturbances caused by the aircraft itself (Fig. 24). It also carries tail surfaces to give stability. An alternative inboard installation (wing-tip or tail) is also used, but although this is neater, dispenses with cable reel and winch, and avoids the accelerations associated with "cable whip," the difficulty of reducing to negligible proportions magnetic anomalies caused by the aircraft is not easily overcome.

For initial surveys of undeveloped areas, the spacing between flights is generally wide. For example, a recent reconnaissance survey in South America employed a spacing of 20 miles. The chances of detecting an ore body in this type of survey are slight, but it would almost certainly reveal probable continuity of major faults, the main sedimentary basins, and major igneous intrusions.

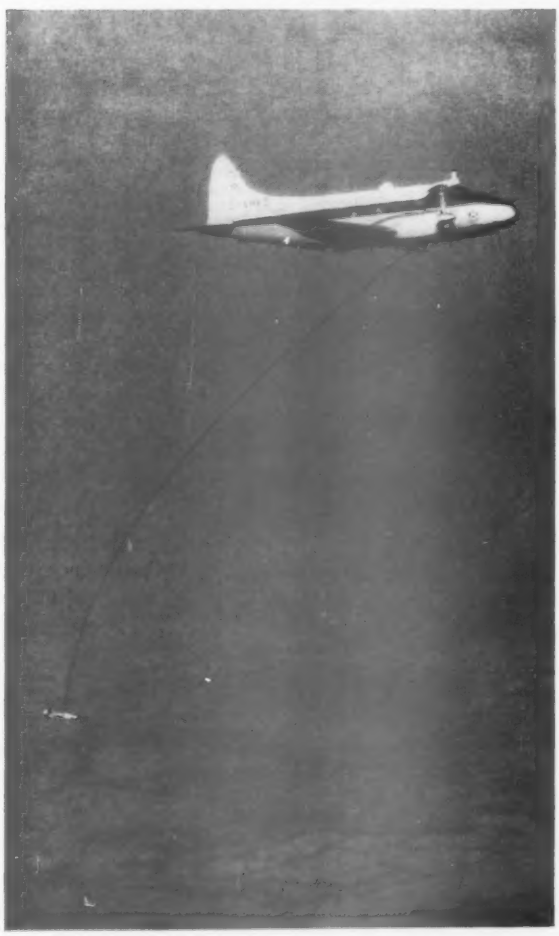


FIGURE 24. Geophysical survey "bird" towed by D.H. Dove aircraft.

The addition of intermediate profiles at 5 mile spacing, where these appeared to be justified, would detect smaller igneous, basement and magnetic features and would quadruple the probabilities for direct ore discovery. In the final stage of exploration a more intensive survey over selected areas would be conducted at closer flight spacings of down to 0·5 miles.

The most recent progress in airborne magnetic surveying has been through the use of nuclear resonance phenomena, and the techniques developed in this country by Elliott Bros. (London) Ltd. have led to a very compact, lightweight magnetometer capable of absolute accuracies of the order of one gamma. The precession frequency of disturbed protons, in a suitable liquid sample, is directly proportional to the total magnetic field under whose influence they are precessing. In the Elliott instrument the period of this oscillation is determined to a high order of accuracy giving an output indication inversely proportional to the total field vector. Initial flight trials of this equipment promise well.

The first airborne electro-magnetic survey was made in Canada in 1949, but many difficulties have been experienced with this method, and progress has been slow. The general procedure is to create a primary field capable of penetrating the ground and which will set up secondary fields wherever electrical conductors are encountered. The secondary fields will be of the same frequency but different amplitude and phase from the primary field. By measuring these effects a conducting ore body may be located as to depth and, by assuming certain shape and attitude, classified by conductivity. In the early days surveys were made from helicopters at very low altitude, the primary field being provided by a ground cable. But penetration is also a function of the distance between transmitter and receiver and in another method the receiver was suspended in a "bird" some 500 ft. behind a transmitter aircraft. This increased penetration, but the length of cable imposed limitations on flying height, especially in turbulent weather conditions. Moreover, even such small variations in transmitter-receiver separation as could occur under normal flying conditions produced errors of as much as 3 per cent in measured amplitude.

One solution to these problems is claimed for the rotary field electromagnetic system, devised by H. Hedstrom and R. Tegholm in Sweden, by which the field is circularly polarised and is thus of equal strength in all directions perpendicular to the axis of rotation. Recordings are remarkably independent of variation in distance between transmitter and receiver, although maximum average separation is still vital to effective penetration. This is especially important in such areas as Central Africa, where valuable sulphide ore bodies are overlain by several hundreds of feet of overburden. Using the rotary field EM, two aircraft may be employed, the leading aircraft carrying the receiver coils in a "bird" at the end of a short cable (80 ft. to 100 ft.) and the rear aircraft, some 800 to 1,000 ft. behind, carrying the transmitter coil.

A survey of this type has recently been completed successfully in East Africa using two D.H. Rapide aircraft at flying heights of 300 ft. and 280 ft. respectively. Greater independence of weather conditions, notably turbulence, is achieved and this must be considered when comparing costs of survey by this method, using two aircraft, with those of earlier single aircraft systems.

Concluding Remarks, on More Recent Progress and Some Thoughts for the Future

So long as social and economic development continues then so long will measurement and assessment need to be made of the earth and its natural resources. Having taken to the air, surveyors may be expected to remain there, whether their interest is in the size and shape of the land, its vegetational covering or the rocks and minerals which lie beneath its surface.

In photography, the striving after increased cover per exposure is a natural one and has an economic spur. It may be satisfied by higher altitude photography; it may, alternatively, be met by a new camera which has appeared on the market only during the past few months. It is known as the RC9 camera and uses a new "super wide angle" (120°) lens (Fig. 25). The new lens will give a photographic scale of 1 : 90,000 (or a total coverage of 164 square miles per exposure) from a flying height of 25,000 ft., which is within the range of piston-engined aircraft, whereas the same scale would be obtainable only from 45,000 ft. with present six inch focal length lenses. Further, the resolving power of the "Super Aviogon" is only slightly inferior to that of the Aviogon at all angles up to 90 mm. from centre, while the distortion is below 0·050 mm. and should be capable of elimination at the same time as earth curvature and refraction.

Possible applications of this lens, advantages which may accrue, and the pitfalls likely to be encountered, present an interesting exercise in crystal-gazing. From one point of view, an area such as Central Australia seems well suited to photography of this type, combined perhaps with heighting from an Airborne Profile Recorder. On the other hand, the distortion of relief which occurs near the edge of the format, the possibility of dead ground in regions of high relief and the economic disadvantage of being unable to use this type of photo-

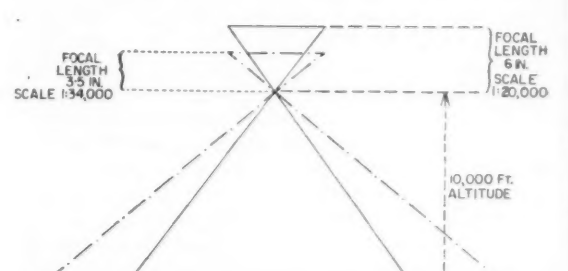

FOCAL LENGTH 3·5 IN. SCALE 1:34,000
FOCAL LENGTH 6 IN. SCALE 1:20,000
10,000 Ft. ALTITUDE
15,000 Ft. PRESENT WIDE ANGLE COVERAGE
26,000 Ft. COVERAGE OF SUPER WIDE ANGLE

FIGURE 25. Ground coverage from wide angle and super wide angle cameras.

FIGURE 26. Portion of an aerial photograph (actual size) showing "reseau" or reference grid used for co-ordinate measurements.

graphy in any existing plotting machines are all aspects which will require appraisal in the cold light of practical surveys.

A method for aerial triangulation of which we are likely to hear much more, is one already pioneered in this country by our own Ordnance Survey. Instead of using optical or mechanical systems to link the photographs together, this method uses co-ordinates measured with respect to the centres of individual photographs. The restitution procedure is then mathematical. It is known as the analytical method and depends for success upon the existence of electronic computational facilities, high resolution photography, a stereocomparator to measure co-ordinates and record them automatically and, for preference, a grid or "reseau" system which will be imprinted unobtrusively on each photograph (Fig. 26). The latter is not essential, but does appreciably simplify the making of accurate observations, as well as providing an elegant method for the introduction of such small corrections as may be required to compensate for differential film distortion, residual lens distortion, and earth curvature and refraction effects. A reseau can only be introduced satisfactorily to a register glass type camera since it is usually engraved on the register glass itself. Cameras of the vacuum type do not possess a surface so conveniently placed.

In this connection the introduction of the new British Hilger and Watts F105 camera, manufactured under contract to the Ministry of Supply, may be an event of some importance. This camera is of register glass/reseau principle and incorporates the new Wray distortion-free survey lens with 1/1,000 second shutter. The first prototype is at present (August 1959) undergoing flight trials and it seems likely that more will be heard of this camera in the future.

Surveys for title to land seem likely to grow in importance as pressure of population on land increases. To what extent this need will be met, as presently dependent territories become independent, may well be influenced by the effectiveness of private air survey agencies in the areas concerned. However political pressures may direct priorities, no other means than air survey, in one form or another, can hope to meet cadastral survey needs in time. It is to be hoped that no obstinate clinging to former methods will prevent a fair appraisal of the advantages and accuracy which air survey has to offer.

There remain some areas, in polar regions, where mapping by conventional air survey methods may prove impracticable. In the Antarctic, some photography has already been done. In 1956-57 a British commercial organisation photographed 35,000 square miles in the Graham Land peninsula, using two Canso amphibian aircraft and Williamson Eagle IX cameras, while the Australian authorities intend to send their first RC9 super-wide-angle camera to the Antarctic for a further photographic programme in the 1959-60 summer season.

But the areas involved are so vast that American plans for the production of 1/1M scale maps of the whole six million square miles of Antarctica provide for methods hitherto regarded as unconventional. In proposals submitted to a meeting of the Special Committee on Antarctic Research, at Canberra, Australia, in March 1959[13], they envisage the use of two types of radar photography, both from an altitude of 50,000 ft. One, search radar, would give a scale of 1/2,500,000 showing a picture of the ground within a radius of 100 miles, while side-looking radar would give larger scale cover up to a distance of 45 miles either side to be used in interpretation. Flight lines would be 45 miles apart, located by an inertial navigation system, radar altimeters (APR) would provide ground elevations, and such additional astrofix ground control as might be required would be surveyed by parties positioned and supplied by air.

These are extreme measures, activated by the difficulties of climate and terrain likely to be encountered in the Antarctic. Yet in 1958 no less than 84 per cent of the whole World's land surface was unmapped except at scales smaller than 1 : 75,000, and some 35 per cent had no maps at all[2]. Perhaps what now appear to be extreme measures may soon be adopted more widely.

Airborne geophysical surveying can scarcely fail to expand in scope. The aeroplane has become a flying laboratory and it seems not unlikely that gravity will soon be added to magnetism, conductivity and radioactivity, already exposed to survey from the air. Knowledge of gravity anomalies, even though extracted from a profile "smoothed" by the averaging technique necessitated by airborne observations, would be of real value to prospectors in virgin territories[16]. Gravity differences have previously been surveyed deliberately and to a high degree of accuracy by classical ground methods—but the need of the present day is for extensive rather than intensive survey. Vast areas need to be checked rapidly and methodically for the existence of resources which would justify investment in development.

Presenting the broad picture rapidly and accurately, air survey in all its forms meets this need. Aerial photography, aerial mapping, and geophysical surveys are all of inestimable value in newly developing territories, chiefly so because they enable very large areas to be surveyed with a high degree of consistency and with increasing accuracy. Who would have thought, forty years ago, of height measurements from the photographs to an accuracy of one five thousandth part of the flying height? Who can foretell the extent to which the Earth's resources may be revealed to aerial surveying in the years to come? The aeroplane is now the handmaiden of measurement; it provides the elevated and rapidly moving platform from which observations may be made. Progress in methods of measurement, photographic and otherwise, has been immense during the past decade, and since survey is vital to newly developing territories, it seems likely that much greater advances are yet to be made as the peaceful development of the world continues.

ACKNOWLEDGMENTS

I have received valuable help in the preparation of this paper from discussions with Group Captain F. C. V. Laws, Mr. R. G. Miller, Mr. M. Brunt, Mr. G. Whittle, and the Sierra Leone Development Company Ltd., and I am indebted to the Board of Fairey Air Surveys Ltd. for permission to use and reproduce much of the material contained therein.

REFERENCES

1. BOURNE, R. (1928). Aerial Survey in Relation to the Economic Development of New Countries, with Special Reference to an Investigation carried out in Northern Rhodesia. Oxford Forestry Memoirs, No. 9, 1928.
2. BROWN, R. LL. (1958). Progress of World Mapping. *The Times Atlas*, Vol. I, 1958.
3. COLLINS, M. O. (1959). Kariba, the Survey Story of a Lake. *Proceedings of Commonwealth Survey Officers Conference*, 1959.
4. FRANCIS, E. C. and WOOD, G. H. S. (1955). Classification of Vegetation in North Borneo from Aerial Photographs. *The Malayan Forester*, XVIII, 1, 1955.
5. GROVE, A. T. (1958). The Ancient Erg of Hausaland, and Similar Formations on the South Side of the Sahara. *Geographical Journal*, CXXIV, 1958.
6. LORD HAILEY (1945). *An African Survey* 1945. Oxford University Press.
7. HUXLEY, ELSPETH (1959). *Kenya Weekly News*, May 15th 1959.
8. MILLER, R. G. (1957). The Use of Aerial Photographs in Forestry in British Colonies. Colonial Office, Misc. 528, London, 1957.
9. *Report of the East Africa Royal Commission* 1953-5. H.M.S.O. Cmd. 9475.
10. SHOWLER and HAMILTON (1958). Shoran Trilateration in the Arctic Islands. *Canadian Surveyor*, July 1958.
11. SMITH, W. P. and WHITTAKER, B. B. (1959). Photogrammetry and Land Tenure Surveys, with Particular Reference to Uganda. *Photogrammetric Record* III, 13th April 1959.
12. *What the Native Land Husbandry Act means to the Rural African*, Government Printer, Salisbury, Southern Rhodesia.
13. WHITMORE, G. D. (1959). Topographic Mapping in Antarctica. *Proceedings C.S.O.C.*, 1959.
14. WILSON, A. M. Hiran Aerial Electronic Surveying.
15. WHITTLE, G. and KISK, H. J. C. Geological and Photogeological Reconnaissance, Ubu Rajang, Eastern Sarawak (unpublished).
16. Fairchild Aerial Surveys Inc., LaCoste and Romberg Gravity Meter Exploration Co., Airborne Gravity Meter Test, 31st July 1959.

MR. MASEFIELD:—They had heard a fascinating lecture, of extraordinary interest. He could not help reflecting as he heard Mr. Smith talking, how much they all enjoyed jig-saw puzzles and "looking over the hedge into our neighbours' gardens." And for those who rather liked flying as well here seemed a wonderful business which combined, in delightful proportions, flying, jigsaw puzzles, and legitimate curiosity of what was going on on the other side of the hedge. He was sure they had a lot of questions they would like to ask Mr. Smith, but by tradition, there was no discussion of these Named lectures of the Society. They were supposed to be delivered from pontifical height from which there could be no possible comment in any direction, except thanks. Accordingly he would ask Mr. David Keith-Lucas to propose a Vote of Thanks to their Commonweath Lecturer.

D. KEITH-LUCAS, F.R AE.S.:—They had been treated to a fascinating lecture by a man who was a master of his subject. He was essentially a practical man, as any man with his name ought to be. He thought "Smiths" should be strong men, practical men and honest men, and he thought that this Smith had those three qualities in abundance. He had invited them tonight to partake of what to him was meat and drink. He had invited them to his table, and had given them a very satisfying and wholesome meal.

He thought sometimes they fell into the error of going only to those lectures which were on their own subject. Lectures which, with a little stretch of the imagination, they might have given themselves. He could not have given that night's lecture. He felt that he had dined out; he had learnt something that he would not have run into in his ordinary daily work. Two things in particular had come out of it for him. The first was that he thought it was always good to learn how aircraft were used, especially those who were concerned all day long with the inner mysteries of the aircraft. In teaching them how those aircraft were used, Mr. Smith had re-affirmed the lesson which many of them found very hard to learn—that, just occasionally, it was the equipment which determined the aircraft, and not the other way round. The other thing which fascinated him particularly was to observe the cross-fertilisation which was an essential part of all science and engineering. For example, in his own particular little corner of the aeronautical world, he had recently come upon two totally different applications of wide angle lenses. One was in connection with target drone aircraft where the lens was used to record the track and miss distance of the missile. That could be looked upon as "Air Survey" of a particular type—air-to-air, instead of air-to-ground. The other application was as a projection lens for projecting the landscape of a helicopter simulator. That could

be regarded as Air Survey in reverse—starting with the photograph and projecting back to a full-scale representation. So he hoped that Mr. Smith's large lenses would breed a whole range of little "lenticles" to undertake these other jobs.

He thought that they owed Mr. Smith a deep debt of gratitude. He would like to propose a hearty vote of thanks and he hoped that they would accord it in the usual manner.

Following the Lecture a dinner was given by the President and Council at 4 Hamilton Place, at which the following were present:—

Mr. L. R. Ambrose, London Manager, Qantas Empire Airways Ltd.

Dr. A. M. Ballantyne, T.D., B.Sc., Hon.F.C.A.I., F.I.A.S., F.R.Ae.S., Secretary, Royal Aeronautical Society. Mr. A. J. Barrett, B.Sc.(Eng.), M.Sc. in A.E., A.F.R.Ae.S., Head of Technical Department, Royal Aeronautical Society. Dr. K. G. Bergin, M.A., M.D., F.R.Ae.S., Master of the Guild of Air Pilots and Air Navigators. Mr. E. C. Bowyer, C.B.E., Director, Society of British Aircraft Constructors Ltd. Marshal of the Royal Air Force Sir Dermot Boyle, G.C.B., K.C.V.O., K.B.E., A.F.C., Chief of Air Staff. Major G. P. Bulman, C.B.E., B.Sc., F.R.Ae.S., Honorary Treasurer and Member of Council, Royal Aeronautical Society. Mr. W. G. F. Burns, Civil Aviation Adviser, Australia House.

Sir Sydney Camm, C.B.E., F.R.Ae.S., Director, Hawker Siddeley Aviation Ltd.; Past President and Member of Council of the Royal Aeronautical Society. Professor A. R. Collar, M.A., D.Sc., F.I.A.S., F.R.Ae.S., Professor of Aeronautical Engineering, University of Bristol; Vice-President of the Royal Aeronautical Society. Mr. J. R. Cownie, B.Sc.(Eng.), Member of Council, Royal Aeronautical Society.

Sir George Gardner, K.B.E., C.B., D.Sc., M.I.Mech.E., F.R.Ae.S., Controller of Aircraft, Ministry of Aviation; Member of Council, Royal Aeronautical Society. Mr. H. H. Gardner, B.Sc., F.R.Ae.S., Director, Vickers-Armstrongs (Aircraft) Ltd.; Member of Council, Royal Aeronautical Society. Sir Harry M. Garner, K.B.E., C.B., M.A., F.R.Ae.S., Member of Council, Royal Aeronautical Society. Wing Commander E. C. Gartrell, O.B.E., D.F.C., Deputy Air Liaison Officer, New Zealand House.

Mr. G. W. Hall, M.S.A.E., F.R.Ae.S., Chairman, Fairey Aviation Co. Ltd. Brigadier M. Hotine, C.M.G., C.B.E., Director of Overseas Surveys.

Mr. E. T. Jones, C.B., O.B.E., M.Eng., F.R.Ae.S., Deputy Controller, Overseas Affairs, Ministry of Aviation, Past President of the Royal Aeronautical Society. Air Marshal Sir Owen Jones, K.B.E., C.B., A.F.C., B.A., D.I.C., M.I.Mech.E., F.R.Ae.S., Vice-President of the Royal Aeronautical Society.

Mr. D. Keith-Lucas, M.A., M.I.Mech.E., F.R.Ae.S., Technical Director, Short Brothers and Harland Ltd.; Member of Council, Royal Aeronautical Society.

Group Captain F. C. V. Laws, C.B., C.B.E., F.R.Ae.S., Chairman, Fairey Air Surveys Ltd.

Mr. P. G. Masefield, M.A., F.R.Ae.S., Hon.F.I.A.S., M.Inst.T., Managing Director, Bristol Aircraft Ltd.; President, Royal Aeronautical Society. Dr. E. A. Miskin, Reader in Surveying and Photogrammetry, University College, London. Mr. M. B. Morgan, C.B., M.A., F.R.Ae.S., Scientific Adviser, Air Ministry; Member of Council, Royal Aeronautical Society. Dr. E. S. Moult, C.B.E., B.Sc.(Eng.), M.I.Mech.E., F.R.Ae.S., Technical Director, de Havilland Engine Co. Ltd.; President-Elect, Royal Aeronautical Society.

Mr. H. L. Pattison, Civil Aviation Adviser, Canada House. Air Cdre. G. J. C. Paul, C.B., D.F.C., Secretary-General of the Air League of the British Empire. Colonel R. L. Preston, C.B.E., A.F.R.Ae.S., Honorary Secretary-General, Royal Aero Club.

Mr. A. C. F. Rippon, M.P., Parliamentary Secretary to the Ministry of Aviation. Mr. J. A. Ross, Director of Station Services, London Airport, for Trans-Canada Air Lines.

Mr. W. P. Smith, M.B.E., B.A., F.R.I.C.S., 1959 British Commonwealth Lecturer; Director, Fairey Air Surveys Ltd.

Professor E. H. Thompson, O.B.E., M.A., Professor of Surveying and Photogrammetry, University College, London. Mr. W. Tye, O.B.E., B.Sc., F.R.Ae.S., Chief Technical Officer, Air Registration Board; Member of Council of the Royal Aeronautical Society.

Mr. L. A. Wingfield, M.C., D.F.C., A.R.Ae.S., Solicitor to the Royal Aeronautical Society.

Mr. T. A. Wolstenholme, A.R.Ae.S., Group Technical Training Officer, Blackburn and General Aircraft Ltd.; Member of Council, Royal Aeronautical Society.

The Imperial College Hypersonic Gun Tunnel August 1958—July 1959

by

J. L. STOLLERY, D. J. MAULL, and B. J. BELCHER

(*Imperial College of Science and Technology, University of London*)

SUMMARY: This paper briefly reviews the progress made with the Imperial College hypersonic gun tunnel since August 1958 when it came into operation. The tunnel and instrumentation are described together with the results of various measurements made both in the barrel and in the working section. More detailed reports will be published later.

1. Introduction

The gun tunnel is an intermittent hypersonic wind tunnel capable of achieving high stagnation temperatures. The tunnel was pioneered by the Ames Aeronautical Laboratory in the U.S.A.[1] and developed in this country by A.R.D.E. Fort Halstead[2].

The gun tunnel is of the blow-down type with a shock-compression heater to generate the high temperature reservoir of gas. Fig. 1(*a*) shows the principal features, and Fig. 3 the general arrangement of the installation at Imperial College. The tunnel drive consists of a high pressure vessel separated by an aluminium diaphragm from a long tube (the barrel) which contains a light, nylon piston. The diaphragm is burst naturally, and the compressed air accelerates the piston down the tube, so forming a shock wave ahead as shown in the *x-t* diagram, Fig. 1(*b*). Multishock reflection occurs between the nozzle block, fitted into the end of the tube, and the piston face, so heating and compressing the gas in the tube. The piston comes to rest when the pressures ahead and behind are equal. The heated gas breaks a second diaphragm, flows through a convergent-divergent nozzle, past the model in the open jet working section and into the vacuum vessel.

NOTATION

α	incidence
d	body diameter
h	step height
l	prong length or plate length ahead of step
M	Mach number
m	piston mass
mS	millisecond
ρ	density
p	pressure
r	shoulder radius
s	length of separated flow region
T	temperature
t	time
U_p	maximum piston velocity
x	distance

Received 14th *August* 1959.

Suffixes

0	stagnation conditions
1	barrel conditions
4	high pressure vessel conditions
∞	test conditions

2. Tunnel Performance

The performance of the gun tunnel has been calculated in Ref. 3. The chief simplifying assumptions are that the piston mass is neglected, and that the shock wave travelling ahead of the piston reflects once from the end of the barrel and once from the piston face, subsequent changes in the compressed gas being isentropic. The results of these calculations are summarised

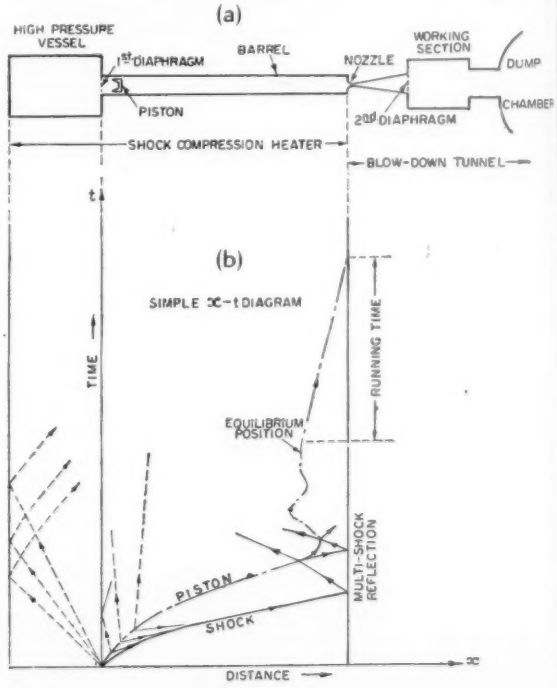


FIGURE 1. The hypersonic gun tunnel.

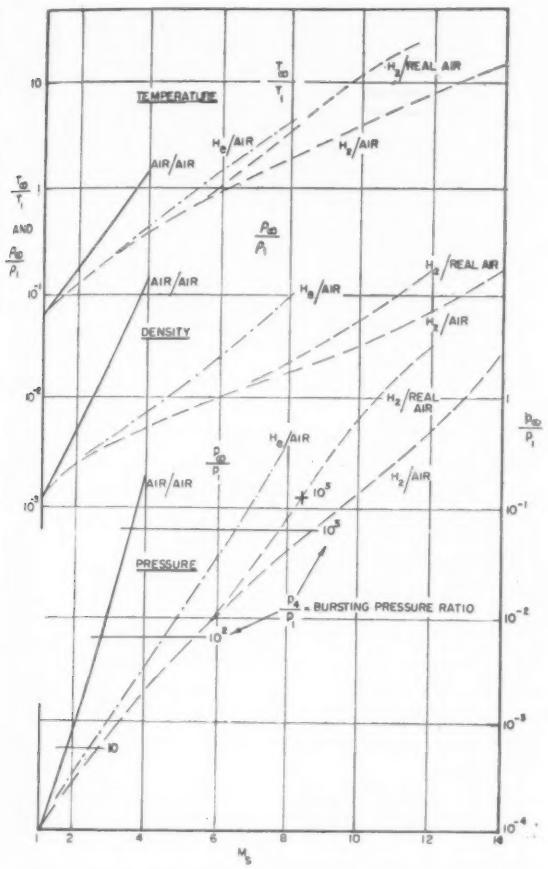


FIGURE 2(*a*). Gun tunnel performance and test conditions.

in Fig. 2. The pressure, density and temperature of the air flow through the working section are shown in Fig. 2(*a*) for three different driving gases, hydrogen, helium and air. The driving gases were assumed perfect, but both real and perfect gas properties were used for

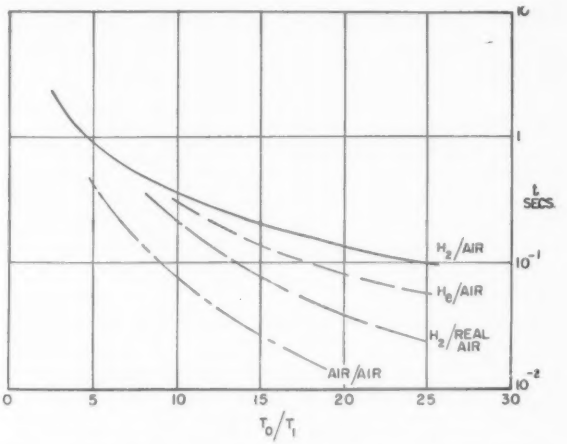


FIGURE 2(*b*). Running time plotted against stagnation temperature. Throat diameter = 0·2 in.

the driven gas (air). Fig. 2(*b*) plots the tunnel running time against the stagnation temperature of the test gas for a nozzle expansion ratio of 225. It can be seen that real gas effects halve the running time at high stagnation temperatures. The duration of flow is relatively long since all the air in the barrel must pass through the throat of the convergent-divergent nozzle. For higher test Mach numbers the throat diameter is reduced and hence the running time is increased.

3. Mechanical Construction

A general arrangement drawing is shown in Fig. 3. The high pressure vessel is mounted on a castored trolley, the tube on two rollers.

3.1. HIGH PRESSURE VESSEL

This is a Mk. 12, Admiralty torpedo vessel, 18 in. diameter, 4 ft. 6 in. long, capacity 6·4 cu. ft., working pressure 1,000 lb./in.^{2}. One end has been modified to take a 3 in. internal diameter neck supporting a heavy

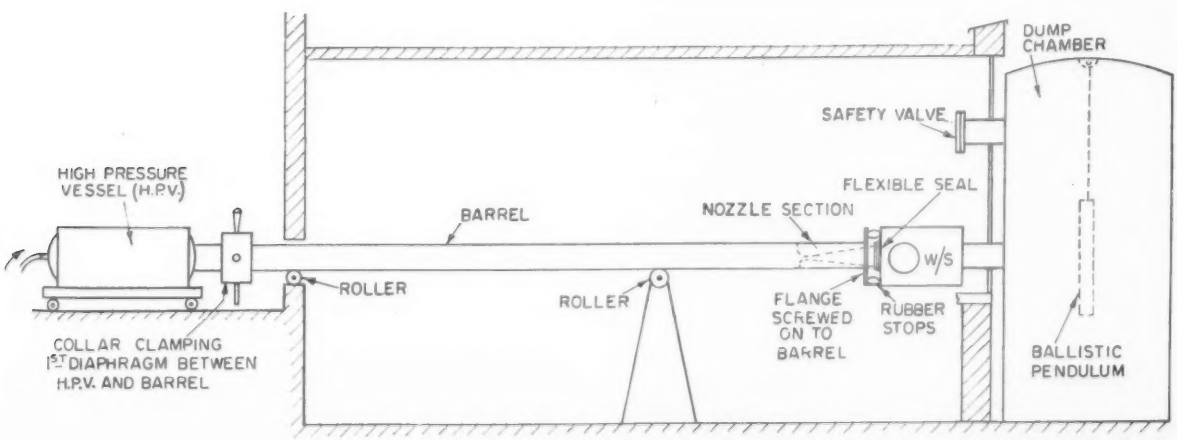


FIGURE 3. General arrangement of gun tunnel.

collar. The collar screws on to the barrel, and clamps the first diaphragm which separates the driver gas from the test gas in the barrel.

3.2. BARREL

The barrel is a thick walled tube of alloy steel, chromium plated on the inside surface. The bore is 3·2 in., the outside diameter 8 in. One end of the tube is screwed to take the collar mentioned above, the other end is bored out to take the nozzle block assembly.

3.3. NOZZLE

A conical contraction (included angle = 90°) leads to a cylindrical throat of 0·20 in. diameter and is followed by a conical expansion (included angle = 7½°) to an exit diameter of 3 in. The nozzle block is made in three parts, the throat section is made from brass and the other parts of steel. The whole nozzle assembly is held inside the barrel by a clamping ring which also secures the second diaphragm.

3.4. FLEXIBLE SEAL

To prevent vibrations of the tunnel drive section being transmitted to the working section a flexible seal is used (*see* Fig. 3).

3.5. TEST SECTION

The jet from the nozzle exhausts into a 2 ft. long, 14 in. × 12 in. box of welded channel section steel. Hinged side plates contain 5 in. diameter schlieren windows. The test section is connected to the vacuum vessel by a 2 ft. length of 7 in. diameter pipe.

3.6. VACUUM VESSEL

The vacuum vessel which is a welded, steel cylinder with domed ends, has a volume of 300 cu. ft. It is evacuated by an Edwards rotary pump (Type GKD 110, displacement 110 cu. ft./min.). As a safety precaution a plate of brass is hung inside the vessel opposite the jet entry. The plate would act as a ballistic pendulum should any part of a model break off and fly downstream.

3.7. GAS SUPPLY

The driver gas is air at pressures up to 1,000 lb./in.² supplied by the department's compressed air plant. Provision is being made to use air at higher pressures and also helium.

4. Instrumentation

4.1. SCHLIEREN SYSTEM

A double-pass schlieren system has been used. Both the single concave mirror and the image lens are of 10 ft. focal length and the image is the same size as the object under examination. The light source is focused on to the slit between two knife edges, one of which is silvered to reflect the object image to the camera.

4.2. SHADOWGRAPH

The light source is focused on to a 1/16 in. diameter hole placed at the focal point of the concave mirror. Thus a parallel beam of light is shone through the test section on to a photographic plate. For the multiple spark source a focused shadowgraph system was used.

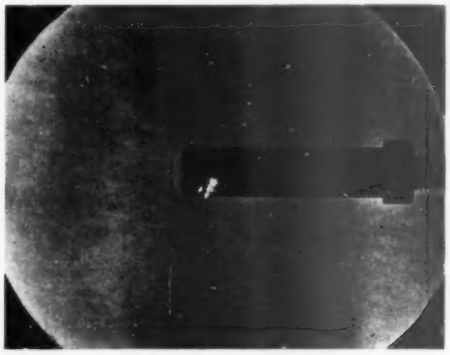


FIGURE 4. Shadowgraph picture of flow past a blunt cylinder. Continuous light source operating from rectified a.c.

4.3. LIGHT SOURCES

For a continuous source a 250 watt mercury vapour lamp has been used, operating on rectified a.c. This is not entirely satisfactory since the supply ripple gives large variations of light intensity. This source was used in conjunction with a modified F24 camera, which has a focal plane shutter. Thus variations in light intensity can be clearly seen as bands across the photograph, as in Fig. 4. The exposure time was normally about 1/300 sec.

Both a single spark source and a Cranz-Schardin multiple spark source were lent by the Aerodynamics Division of the N.P.L. The Cranz-Schardin unit provided a sequence of up to eight sparks at ten miscrosecond intervals. The spark duration was one to two microseconds.

4.4. DELAY UNIT

A delay unit was constructed in order to trigger the spark source a controllable time after the bursting of the first diaphragm. In the same way as the micro-wave recording the burst was detected by a microphone, the signal then being passed to amplifier, shaper, gate, and gate control units (*see* Section 5). The output from the gate control unit was then fed to the delay unit shown in Fig. 5.

The valve (*V*2) of this circuit is arranged to have one stable state and one quasi-stable state. A short, positive pulse sends it from the stable to the quasi-stable state where it stays for a time depending on the circuit constants. These are variable by the switch *Sw*2 and

TABLE I

	Type A *Southern Instruments* G.207B	*Type B*, C.E.C. 4–312A
Pressure range	0–2000 lb./in.²	0–15 lb./in.² abs.
Length	2·25 in.	0·75 in.
Diameter	0·70 in.	0·50 in.
Excitation	up to 30 volts	5 volts
Output	up to 20 mV. full scale	20 mV. full scale

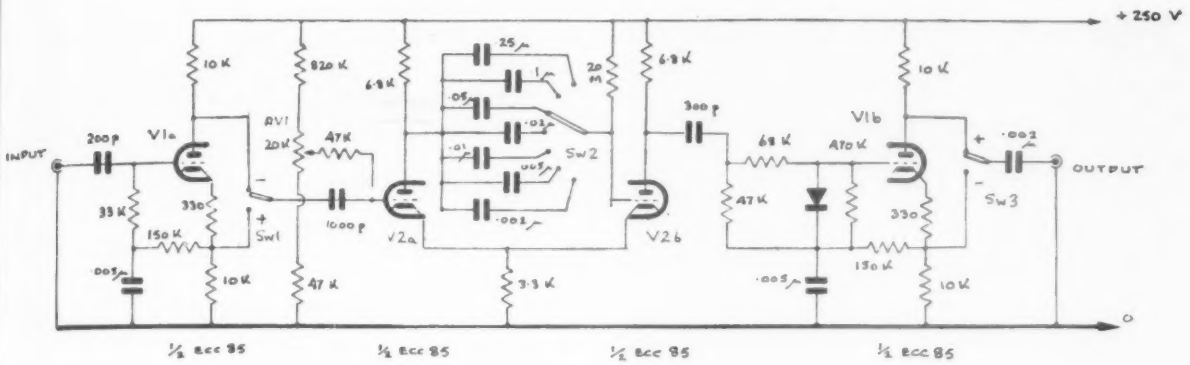
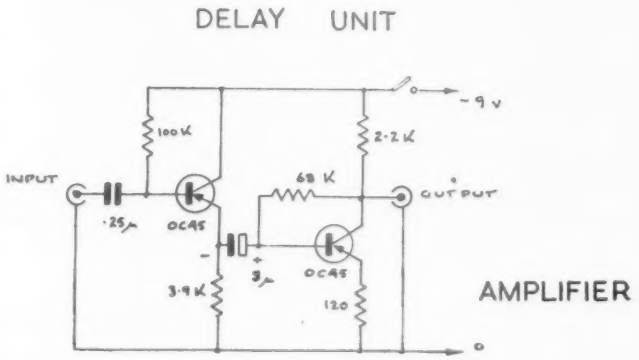


FIGURE 5. Delay unit and (*below right*) transistor amplifier.



the potentiometer *RV*1. When the circuit returns to its stable state, a negative pulse is delivered to the triode *V*1*b*.

Since a positive pulse is needed to drive the spark source, the triode (capable of sending a pulse of either sign) is switched to positive. A similar triode precedes the monostable multivibrator (*V*2).

4.5. PRESSURE TRANSDUCERS

All pressure measurements have been made with transducers of the resistance type. These were chosen in preference to the piezo-electric gauges because they are more easily calibrated statically. The characteristics of the transducers are listed in Table I.

5. Measurements in the Barrel

5.1. PISTON MOTION

Some details of this work have already been reported in Ref. 9 but are included here for completeness. To study the effect of bursting pressure and piston mass on the motion of the piston down the barrel, a microwave technique was used[4]. If the front of the nylon piston is faced with a conducting material, electromagnetic waves, which can be excited in the barrel, will reflect off the piston and also off the nozzle block. Hence, if the piston is any multiple of a half wavelength from the nozzle, standing waves will occur and the barrel becomes a resonant cavity. By detecting and recording these resonances an analysis of the piston motion is possible. The circuit used is shown in Fig. 6.

To excite the electromagnetic waves, power from a 200 mW. 10 cm. Klystron oscillator is fed via a directional coupler to probes mounted on the nozzle block. These probes are arranged not to interfere with the normal working of the tunnel while still exciting a radially symmetric mode (TM_{01}) in the barrel. During a run they are protected by a nylon block. Conditions at the probe will depend on the relative phases of the reflected wave and the wave being launched. The probes are matched so that under conditions of resonance, when these two waves are in phase, nearly all the power arriving at the probes passes into the barrel cavity and is dissipated within it. However, when the piston moves from the resonant position, the reflected wave is out of phase with the launched wave, and only some of the power is able to pass into the barrel. The rest is reflected from the probes back along the co-axial feeder and is detected by the diode on the directional coupler. Hence a resonant point is indicated by a drop in the voltage output from the diode. The drop in voltage is recorded by an oscilloscope and camera. About 50 resonant points have to be measured and, as one sweep of the cathode ray tube has insufficient resolution, a multiple line (raster) display was used. Oscilloscope 1 was arranged to sweep continuously but with the beam blanked off, and oscilloscope 2 brightened up the first beam when triggered from a bursting signal picked up by a microphone. The time base from the second oscilloscope was then added to the diode output to displace consecutive lines on the recording tube producing the raster display. One trouble encountered was that the time-base voltage biased off the diode and reduced the signal to nothing. This was cured by inserting a small, self-contained, transistor, isolating amplifier* between the diode and the adding resistors (*see* Fig. 5). Because of the resulting "ring" and general noise of a burst, the oscilloscope triggered several times. To ensure that only one trace was obtained, a trigger and gate system was adopted. This amplifies and shapes incoming signals

*The specification is: voltage gain 17, frequency response 15 c./sec. to 500 Kc./sec. ± 3dB. with a high input and low output impedance. Two OC 45 transistors are used, *see* Fig. 5.

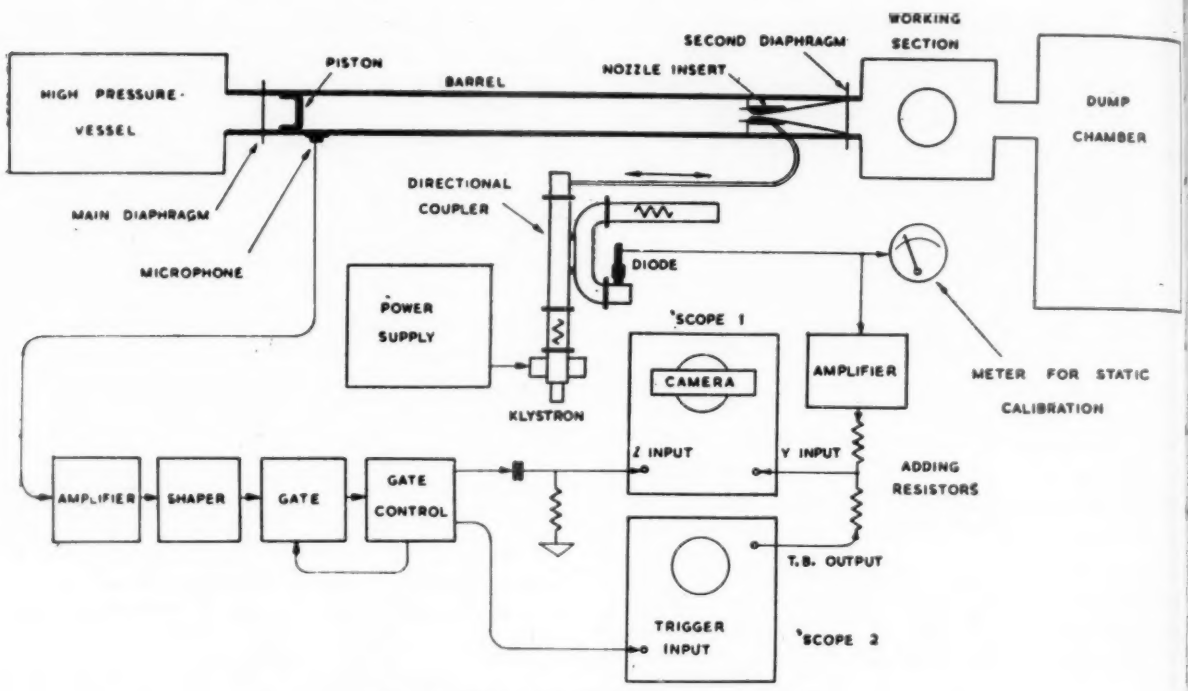


FIGURE 6. Circuit for measurement of piston motion.

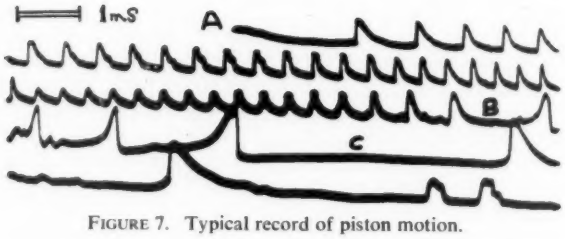


FIGURE 7. Typical record of piston motion.

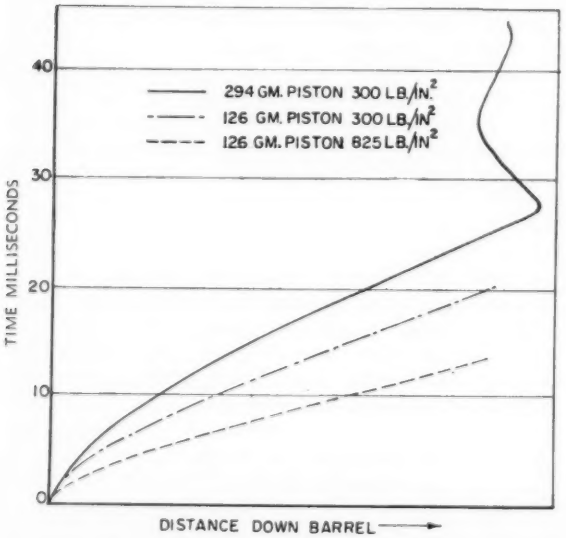


FIGURE 8. Experimental $x-t$ diagrams.

from the microphone and passes them to a gate. A pulse coming from this gate closes it and triggers the second oscilloscope. Hence only one trace is possible before the system is reset by opening the gate manually.

A typical record is shown in Fig. 7. Starting at *A*, which is arranged to be on a resonant point for reference, the distance between pips becomes less, indicating acceleration of the piston, until the third line down where, after a rapid deceleration, the wave shape is seen to reverse, at *B*, indicating that the piston is going backwards down the tube. On the fourth line at *C* another reversal is evident. The resonant points are indicated by positive pips because the amplifier reverses the sign of the signal.

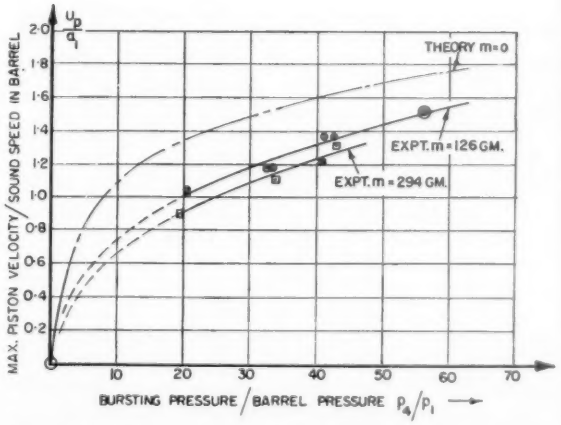


FIGURE. 9. Piston velocity plotted against bursting pressure.

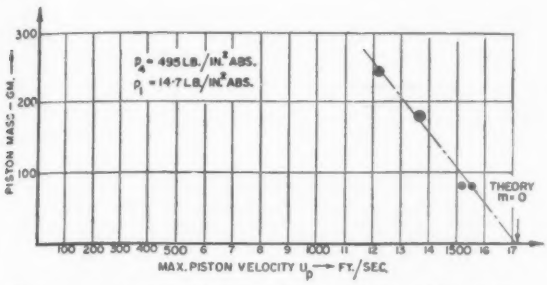


FIGURE 10. Piston velocity plotted against piston mass.

The film records were analysed to give a plot of piston position (x) against time (t) and three traces are shown in Fig. 8. Considerable piston overshoot is visible. From the x–t diagrams maximum piston velocity was measured and is compared with the theoretical zero mass piston velocity in Figs. 9 and 10.

For a standard piston mass of 126 gm. the final velocity increased with bursting pressure and, at the highest bursting pressure ratio used, approached 90 per cent of the theoretical value for a zero mass piston (*i.e.* 90 per cent contact surface velocity). For the tests with constant bursting pressure but varying piston mass, care was taken to keep the piston skirt rigid so that the friction force would be constant for this series. As the piston mass is decreased, so the maximum piston velocity increases. The experimental points extrapolate well to the contact surface velocity.

To get some idea of the friction effect, a piston of standard weight was used without the normal flexible skirt. The results showed little change in initial acceleration but the maximum velocity achieved by the modified piston was about 5 per cent higher.

The initial acceleration of the piston was also measured with the following results: —

Bursting pressure P_4 (lb./in.² abs.)	*Acceleration*
300	4,000 g
485	5,400 g
600	7,200 g
825	15,000 g

The barrel pressure P_1 was 14·7 lb./in.² abs.

6. Measurements in the Test Section

6.1. FLOW DURATION AND DEVELOPMENT

6.1.1. *High speed films*

High speed camera runs at 1,000 and 3,000 frames per second were taken using an Eastman Kodak 16 mm. rotating mirror camera lent by the Ciné Section of R.A.E. Farnborough. These films gave an accurate measure of flow duration and the nozzle starting time together with an indication of flow steadiness. Frames showing the start of the flow are reproduced in Fig. 11. The starting time is about 25 milliseconds. The flow ends smoothly and quickly in 4 to 5 milliseconds.

It was noticeable in one run that the model (a long blunt cylinder with a prong protruding from the front face) deflected appreciably during the flow starting process.

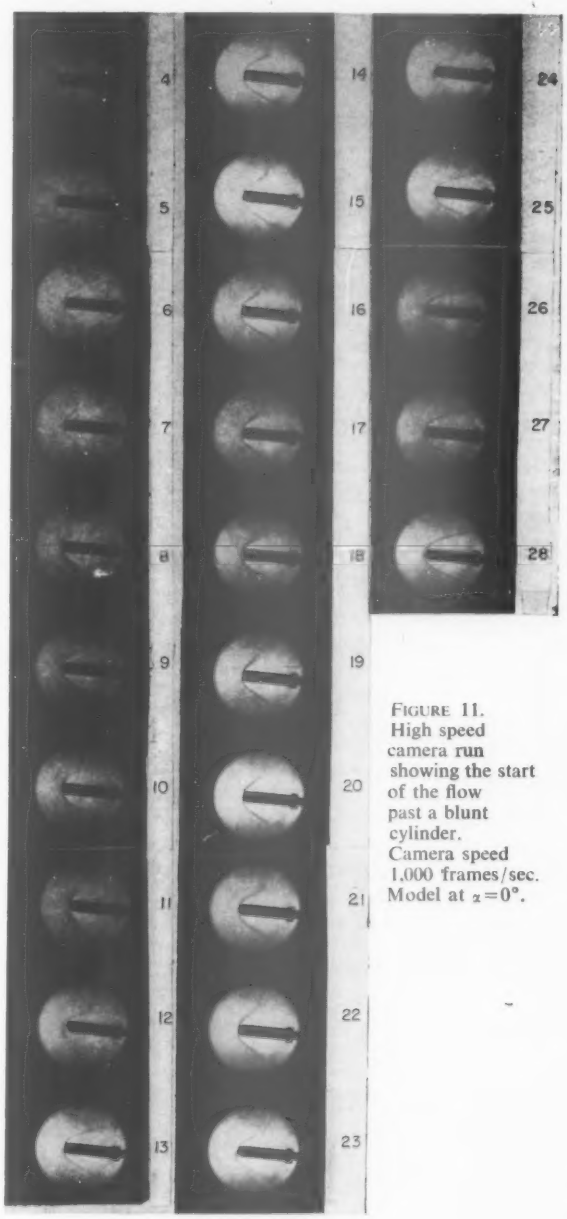
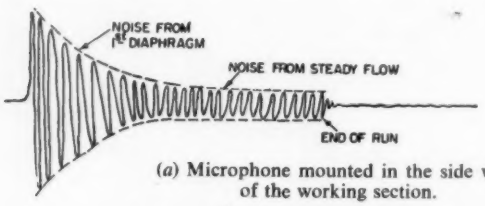


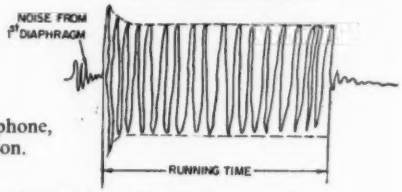
FIGURE 11. High speed camera run showing the start of the flow past a blunt cylinder. Camera speed 1,000 frames/sec. Model at $\alpha = 0°$.

6.1.2. *Microphone Measurements*

The running time has been measured using ACOS $\frac{3}{4}$ in. diameter crystal microphones. These have a high frequency response which is suitable for recording with an oscilloscope. The first microphone used was mounted in a Perspex block on the working section wall. A typical output signal is shown in Fig. 12(*a*) and is difficult to interpret since the noise of the first diaphragm breaking masks the start of the flow. A second microphone was rubber-mounted in the working section and part of the jet ducted through a pipe onto the microphone face. The resulting signal (Fig. 12(*b*)) was large and easy to interpret.



(*a*) Microphone mounted in the side wall of the working section.



(*b*) Ducted microphone, rubber suspension.

FIGURE 12. Sketches showing type of trace.

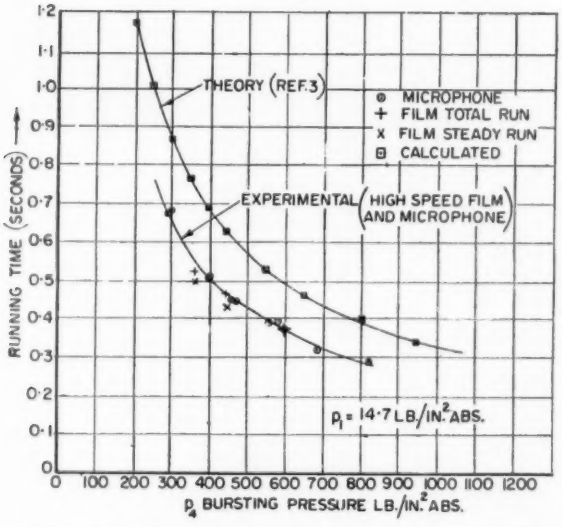


FIGURE 13. Tunnel running time, theory and experiment.

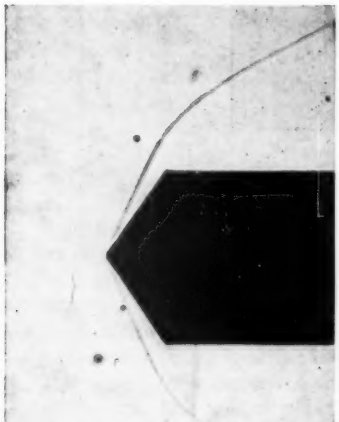


FIGURE 14 (*left*). Flow past a 110° cone. $M = 6{\cdot}8$.

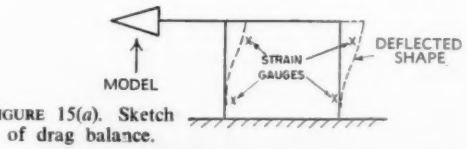


FIGURE 15(*a*). Sketch of drag balance.

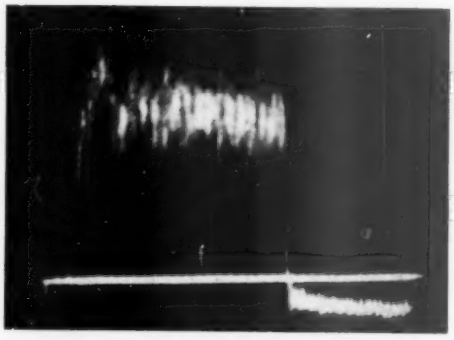


FIGURE 15(*b*). Oscilloscope record of drag.

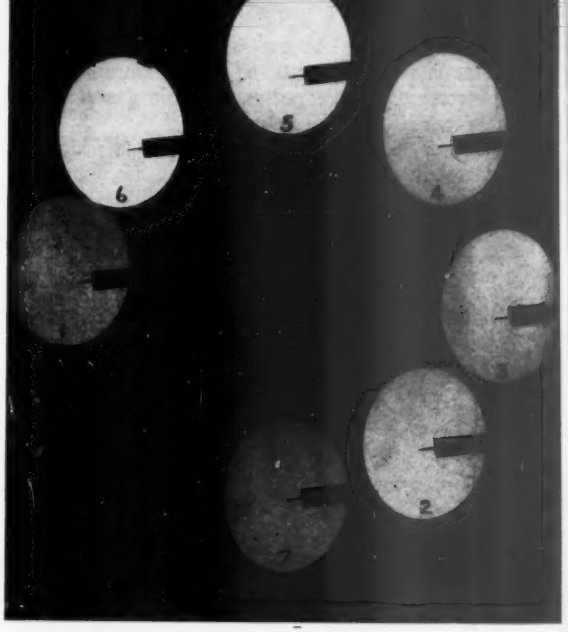


FIGURE 17. Blunt cylinder with prong $l/d = 0{\cdot}75$. Shadowgraph pictures at 10 mS. intervals.

$l/d = 0$ $l/d = 0{\cdot}75$ $l/d = 0{\cdot}75$

FIGURE 16. Flow with and without a nose prong.

The high speed ciné films taken had timing marks produced by a tuning fork and mirror. The total running time (including starting process) measured by film agreed to within 5 per cent with the microphone results after the tuning fork and oscilloscope time base had been calibrated against a crystal oscillator (see Fig. 13).

6.2. MACH NUMBER

An attempt was made to measure Mach number from the angle between the surface of a cone and the attached shock wave. Both 60° and 110° cones were tested. A typical photograph is shown in Fig. 14. The Mach number was found to be $6{\cdot}8 \pm 0{\cdot}5$.

Measurements of stand-off distance (δ) were also made but are unsatisfactory for the deduction of Mach number (M) since δ varies little with M for $M > 4$.

6.3. PRESSURE MEASUREMENTS

Stagnation pressure in the test jet is to be measured using transducer *B*. Traverses will be made both axially and radially to determine the uniformity and extent of the jet. The transducer has a complete bridge network built inside it. The output signal is amplified and displayed on an oscilloscope. The pressure history will also check the running time already measured by microphone and camera.

6.4. FORCE MEASUREMENTS

A simple one-component strain gauge balance has been built and used to measure drag. The balance is schematically shown in Fig. 15(*a*). Four Tinsley 120 Ω Araldite-based strain gauges trimmed to 0·3 in. × 0·3 in. are used and connected in a d.c. energised Wheatstone bridge circuit. The balance is insensitive to lift force and pitching moment but picks up a few per cent of any side load that is applied. The balance has a natural frequency in the drag deflection mode of 500 c./sec. with a model weighing 30 gm. fitted on the sting.

Preliminary measurements show that the balance could be improved by increasing the damping. An oscilloscope trace of drag plotted against time is shown in Fig. 15(*b*), the model tested being a sphere.

7. Flow Visualisation and Preliminary Experiments on Separated Flows

The main investigation has been on the flow around axisymmetric blunt bodies with a nose prong. The boundary layer formed on the prong tends to separate, and a conical shock wave is produced instead of a bow shock wave, the drag of the body being greatly reduced. Previous investigations[5, 6] have shown that the flow and shock pattern were extremely unstable for the case of a flat ended cylinder equipped with a prong, but steady for a hemispherical nosed cylinder with a prong. The objects of our investigations have been (*i*) to find the range of prong lengths for which the flow is unsteady, (*ii*) the effect of nose radius on this unsteadiness, and (*iii*) to determine the mechanism of the oscillation. The models are of brass, the body being ½ in. diameter and the prong a commercial sewing needle.

FIGURE 18. The effect of blowing a jet of air from the front face of a cylinder in a hypersonic flow. $M_\infty = 6{\cdot}8$.

Schlieren and shadowgraph photographs of the flow around the flat ended cylinder with prong showed marked unsteadiness when the prong was just long enough to go through the bow wave. This unsteadiness continued until the prong length was a little more than three body diameters.

Spark shadowgraph results show this oscillation more clearly and are compared with the no-prong case in Fig. 16. An attempt was made to investigate the flow using a high speed ciné camera but, while showing that the oscillation existed, a speed of 3,000 frames per second was not sufficient to clarify the mechanism of the oscillation. This tends to confirm previous estimates[5, 6] of the order of 10^4 cycles per second for the oscillation frequency. Pictures taken using the multiple spark source showed that the frequency is in fact about 25,000 cycles per second. A typical sequence is shown in Fig. 17. A jet of air was also injected against the main stream from a hole in the nose of a blunt body and the resulting shadowgraph photograph is shown in Fig. 18. This flow pattern is similar to a stage in the oscillating flow of Fig. 17, suggesting that in one part of the oscillatory cycle air is fed along the prong.

Since the hemispherically nosed body showed no oscillations of the flow pattern, a series of cylinders were tested having various corner radii. It was found that the radius tended to reduce the range of prong lengths for which oscillation occurred. The results are shown in Fig. 19. Together with the results from Refs. 5 and 6 it is possible to sketch the oscillatory ranges of (l/d) against Mach number for the flat ended cylinder (*see* Fig. 20.

The flow up a step on a flat plate was also investigated. Here the boundary layer separates upstream of the step, if the boundary layer is laminar, then separation is so gradual that any shock waves formed are not

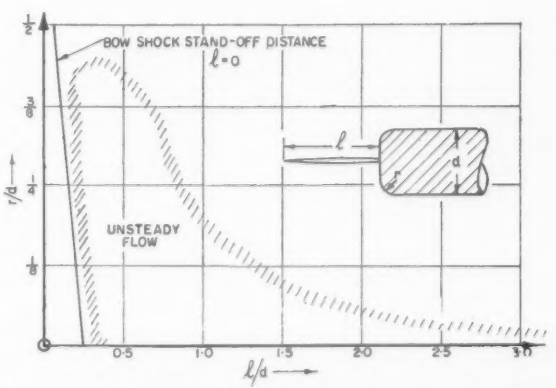


FIGURE 19. The effect of shoulder radius on the flow around a blunt cylinder with nose prong. $M_\infty = 6{\cdot}8$.

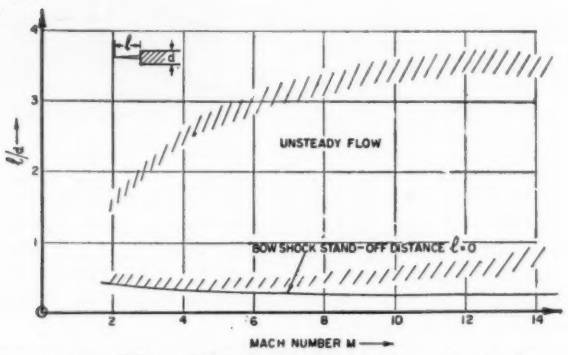


FIGURE 20. Effect of Mach number on the unsteady flow régime. Flat-ended cylinder with prong.

strong enough to show up on shadowgraph photographs (as in Fig. 21). If transition to turbulent flow occurred in the separated layer, then a certain amount of unsteadiness was noticed, confirming the findings of Chapman, Kuehn and Larson[8]. It was found that the position of the separation point was a function of both the step height and the distance of the step from the plate leading edge. The results have been compared with the idealised theory of Moeckel[7] in Fig. 22.

ACKNOWLEDGMENTS

P. D. Church and J. E. Smith have been responsible for the force and pressure measurements respectively. Their help in the preparation of this paper is gratefully acknowledged.

Much valuable advice and help has been obtained from A.R.D.E., R.A.E. and particularly N.P.L. We have also benefited from a free exchange of information with the Aeronautical Engineering Department, University of Southampton.

The authors are greatly indebted to the Department's Workshop staff for their co-operation.

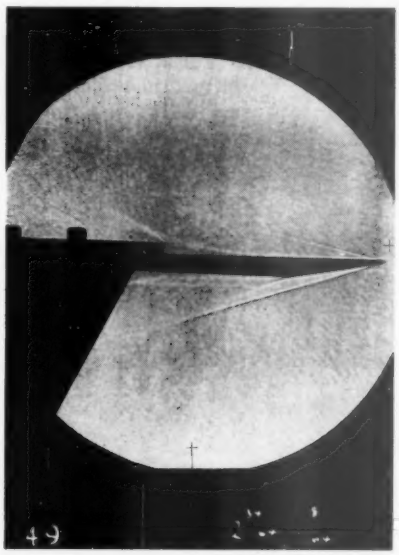


FIGURE 21. Flow up a step with laminar separation.

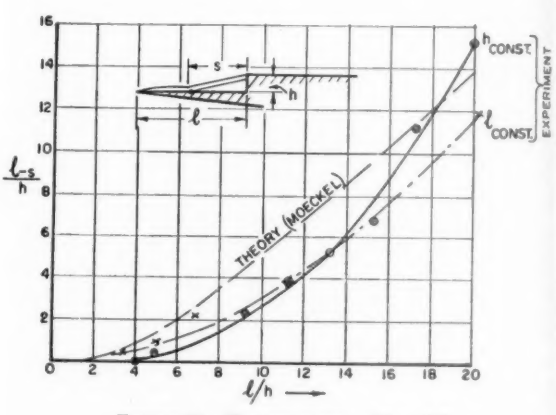


FIGURE 22. Flow up a step. $M_\infty = 6{\cdot}8$.

REFERENCES

1. EGGERS, A. J., HANSEN, C. F. and CUNNINGHAM, B. E. Theoretical and experimental investigation of the effect of yaw on heat transfer to circular cylinders in hypersonic flow. N.A.C.A. RM A55E02 (TIL/4749).
2. COX, R. N. and WINTER, D. F. T. The light gas hypersonic gun tunnel at A.R.D.E., Fort Halstead, Kent. AGARD Report 139.
3. MAULL, D. J. The performance of a hypersonic gun tunnel for real and perfect gases. Imperial College Aero. Report.
4. PENNELEGION, L. (1959). A microwave method of determining the displacement and velocity of a piston in a hypersonic gun tunnel. *Nature*, 24th January 1959.
5. MAIR, W. Experiments on the separation of boundary layers on probes in front of blunt nosed bodies in a supersonic air stream. ARC 14712.
6. BOGDONOFF, S. M. and VAS, E. (1959). Preliminary investigations of spiked bodies at hypersonic speeds. *Journal of the Aero/Space Sciences*, February 1959.
7. MOECKEL, W. E. Flow separation ahead of blunt bodies at supersonic speeds. N.A.C.A. T.N. 2418.
8. CHAPMAN, D. R., KUEHN, D. M. and LARSON, H. K. Investigation of separated flows in supersonic and subsonic air streams with emphasis on the effects of transition. N.A.C.A. T.N. 3869.
9. BELCHER, B. J. Measurement of the effects of piston mass and bursting pressure on the motion of a piston in a hypersonic gun tunnel. *Nature*, 17th October 1959.

TECHNICAL NOTES

A Controlled Experiment on the Subjective Effects of Jet Engine Noise

by

W. C. T. COPELAND*, I. M. DAVIDSON†, T. J. HARGEST† and D. W. ROBINSON*
(**National Physical Laboratory*, †*National Gas Turbine Establishment*)

WITH THE CO-OPERATION of 1,600 members of the public a series of aircraft noise assessment tests was made at the 1959 Farnborough Air Show to obtain further information on the way in which the perception of these noises is influenced by subjective effects. This provisional analysis shows that Beranek's empirical method for assessing the perceived noise level is adequate for the comparison of existing types of fixed-wing aircraft. A secondary part of the experiment, dealing with noise simulating the ducted-fan engine, is also described.

For various reasons the sociological consequences of noise cannot be assessed directly from a simple meter reading; a fact which has long been understood[1]. The unwilling observer of a noise naturally rates it in terms of some such human criterion as "loudness" or "disturbance", which qualities are the respective bases of various subjective noise assessment scales, *e.g.* those of Stevens[2] and Beranek[3, 4] respectively.

To the manufacturers and operators of aircraft and their engines this subject will become increasingly important. The noise of a civil aircraft already has an important bearing on its rate of utilisation, and for vertical take-off machines of the future it could prove crucial. Looking ahead, it may very well be more economic to design "quiet" engines in the first place than to "silence" them during development; but to do this it is necessary to know just how the noise will be perceived and therefore judged by the aggrieved party.

With these facts in mind, the N.G.T.E. exhibit at the 1959 S.B.A.C. Show included a large scale experiment on some of these subjective effects; an experiment which was planned, prepared and conducted jointly with the staff of the Acoustics Section of the National Physical Laboratory. Previous experiments of this sort, including those on which the existing scales are based, have always been conducted on a relatively small number of subjects, each of whom was therefore called upon to display a high level of critical capacity.

The main purpose of this 1959 experiment was therefore to see whether the relative ratings of selected noises by a large number of representatives of the public would be in accordance with those scales. In view of the present development activity in the ducted fan field, a secondary objective was to learn something of the influence of discrete (compressor or turbine blade) tones on the relative rating of an engine noise.

The experiments were conducted in a small cinema of approximate internal dimensions $19\frac{1}{2} \times 8 \times 7\frac{1}{2}$ ft. high, soundproofed to give such an attenuation (about 50 dB.) of external noise that work could continue undisturbed by the S.B.A.C. Flying Display, and with loudspeakers arranged front and back to give a reasonably uniform sound pattern. One important point was, of course, the degree of co-operation and attentiveness of the audience, for which the evidence was that out of 1,601 attendances there were only 23 spoiled forms, and those mainly from small children or persons wearing hearing aids or using portable noise meters!

Following a 15 minute film and a short plea for co-operation from the steward in the theatre, the tests began with an announcement from the loudspeakers which concluded in one of the two following ways:—

(*i*) "We shall announce each pair of noises as it comes, and you will have two or three seconds between one pair and the next to record your decision. Even if you are doubtful, a guess will be much more valuable to us than a blank space on your paper.

"Once again then, please record which of the two noises in each pair you consider to be the louder.

"Test number one ....."

(*ii*) Exactly as (*i*) except that the words "more disturbing" were substituted for the word "louder".

In all there were four test (magnetic) tapes of which each audience heard only one. The thirty-two noises (sixteen pairs) on each tape were individually "faded up" over about 0·2 seconds, held for four seconds and then "faded down" over about 0·2 seconds, the sounds themselves being high fidelity reproductions of the peak noise of the real or hypothetical aircraft flying past on its climb from an airfield.

The composition of two of the tapes—coded for convenience "Red" and "Yellow"—is given in Table I. In the "Green" and "White" the sixteen pairs were produced in the same order, but the internal order of each pair was reversed—*i.e.* $(A+5)$* versus $(B-5)$ instead of $(B-5)$ versus $(A+5)$ to take account of the bias in judgement arising from the order of presentation. The judgement of loudness was requested on the "Red" and "Green" tapes, and of disturbance on the "Yellow" and "White".

Above the heads of the audience in the cinema there were two monitoring microphones, by means of which the level of reproduction of each and every test noise was recorded on a laboratory type sound level recorder reading true r.m.s. In addition, a 25 per cent sample of the test

Received 1*st December* 1959.

*The notation signifies the overall sound pressure level in dB, *A*, *B*, and so on, being the chosen datum levels of noises *A*, *B*, and so on. The datum levels, though arbitrary, were based on an "intelligent guess" of the expected result in order to avoid trivial comparisons.

TABLE I

COMPOSITION OF THE "RED" AND "YELLOW" TAPES

	First noise (dB.)	*Second noise* (dB.)
Test 1	(*B*−5)	(*A*+5)
Test 2	(*A*−2)	(*B*+2)
Test 3	(*B*+5)	(*A*−5)
Test 4	(*A*+2)	(*B*−2)
Test 5	(*A*+5)	(*C*−13)
Test 6	(*C*−6)	(*A*−2)
Test 7	(*A*−5)	(*C*−3)
Test 8	(*C*−10)	(*A*+2)
Test 9	(*C*+5)	(*B*−2·5)
Test 10	(*B*+4·5)	(*C*−2)
Test 11	(*C*−5)	(*B*+7·5)
Test 12	(*B*+0·5)	(*C*+2)
Test 13	(*D*−5)	(*E*+5)
Test 14	(*E*−2)	(*D*+2)
Test 15	(*D*+5)	(*E*−5)
Test 16	(*E*+2)	(*D*−2)

Note:—These are electrical levels, the datum values being those of:—

A The Super-Constellation

B The Boeing 707/120

C The Vulcan Mark 1

D A "synthetic" noise—a real jet rig noise with artificial Doppler effect and rise and fall of level added to simulate a fly-past

E A hypothetical ducted fan aircraft—basically *D*, but with a 3 kc./sec. square wave added to simulate engine tones before Doppler effect and level rise and fall superimposed.

noises was recorded (magnetically) from the monitoring channel. The sound quality was thus checked by octave band analysis between tests, for, while each test tape played for only 4½ minutes, the duration of the programme cycle (including film show) was half an hour.

Since the design of the cinema involved a compromise it could not be made acoustically perfect and some form of calibration was clearly required. This was done by playing the test noises to a live audience with two vacant seats over which, in the position normally occupied by the subject's head, monitoring microphones were suspended. In this way, by redistributing the audience and the microphones until each seat position was checked, the theatre calibration of Table II was obtained. In addition, mean datum levels of the noises weighted in accordance with the numbers of listeners occupying the various seats are given in Table III. The various noise spectra are plotted in Figs. 1 to 4, which illustrate the highest and lowest individual spectra obtained in the various seats together with a more typical member of the set (Seat No. 13 in each case). In general the differences between spectra for different seats were in the nature of level shifts rather than of spectrum tilt, as is shown by the high degree of correlation between corresponding columns of Table II for S.P.L., phons and P.N. dB.

In analysing the audience replies, the bias in judgement caused by the order of presentation within each noise pair was automatically minimised by combining the results for the "Red" and "Green" tapes; and similarly for the "Yellow" and the "White", although no attempt has yet

TABLE III

WEIGHTED MEAN DATUM LEVELS

Noise		S.P.L. dB. re. 2×10^{-4} dyne/cm.^{2}	*Stevens' Phons*	*Beranek's rating* P.N.dB.	*Mean deviation* dB.
Loudness tests	*A*	103·0	106·7	105·3	±2·3
	B	97·4	107·0	109·4	±1·6
	C	102·5	109·5	110·2	±1·7
	D	93·9	105·8	109·5	±2·1
	E	90·6	102·3	106·0	±2·4
Disturbance tests	*A*	103·2	106·9	105·5	±2·3
	B	97·4	107·0	109·4	±1·6
	C	102·5	109·5	110·2	±1·7
	D	93·9	105·8	109·5	±2·1
	E	90·6	102·3	106·0	±2·4

TABLE II

SOUND VARIATION OF INDIVIDUAL NOISES FROM THEIR DATUM LEVELS IN THE CINEMA

Noise	*Overall sound pressure level* (dB.)					*Stevens' Phons*					*Beranek's rating* (P.N. dB.)				
	A	*B*	*C*	*D*	*E*	*A*	*B*	*C*	*D*	*E*	*A*	*B*	*C*	*D*	*E*
Seat 1	−1·5	−0·4	−0·5	−2·4	−2·1	−0·7	−1·0	−1·5	−1·8	−2·3	−0·3	−2·4	−0·2	−3·5	−3·0
Seat 2	−2·5	−0·4	−2·0	−1·4	−1·1	−1·7	−1·0	−1·5	−1·8	−1·3	−1·3	−2·4	−2·2	−2·5	+1·0
Seat 3	−1·0	−0·4	−0·5	−1·4	−1·6	−0·7	−2·0	−0·5	−2·8	−3·3	−0·3	−1·4	−0·2	−2·5	−3·0
Seat 4	+2·5	+0·1	+0·5	−0·9	−1·6	+3·3	−1·0	+0·5	−0·8	−3·3	−2·7	−1·4	−0·2	−2·5	−3·0
Seat 5	−4·5	−0·9	−1·5	−1·9	−2·6	−4·7	−1·0	−1·5	−1·8	−2·3	−3·3	−1·4	−0·2	−2·5	−2·0
Seat 6	+0·5	−1·9	−3·0	−1·9	−2·1	−0·7	−2·0	−2·5	−1·8	−2·3	−0·3	−2·4	−2·2	−1·5	−2·0
Seat 7	−3·0	−1·9	−2·0	−2·4	−3·1	−2·7	−1·0	−1·5	−1·8	−3·3	−2·3	−1·4	−1·2	−2·5	−3·0
Seat 8	−2·0	−1·4	−2·0	−2·4	−2·1	−0·7	−2·0	−2·5	−1·8	−2·3	−1·3	−2·4	−2·2	−1·5	−2·0
Seat 9	−1·0	−1·9	−1·5	−1·9	−1·6	+0·3	−2·0	−1·5	−1·8	−1·3	−0·3	−2·4	−2·2	−1·5	−1·0
Seat 10	−2·0	−0·9	−1·5	−1·4	−2·6	−1·7	−2·0	−1·5	−1·8	−2·3	−1·3	−2·4	−1·2	−1·5	−2·0
Seat 11	−1·0	−0·4	−0·5	+0·1	−0·6	−1·7	−1·0	−0·5	−0·8	−1·3	−1·3	−1·4	−0·2	−0·5	−1·0
Seat 12	+1·0	+0·6	+1·5	+0·6	+1·1	+0·3	0·0	+0·5	+0·2	+0·7	−0·3	−0·4	−0·2	+0·5	+2·0
Seat 13	0·0	+0·1	+0·5	+0·1	−1·1	+0·3	0·0	+0·5	−0·8	−1·3	−0·3	−0·4	+0·8	−0·5	−1·0
Seat 14	+1·0	+1·6	+0·5	+1·1	+1·9	+1·3	+2·0	+0·5	+1·2	+2·7	+1·7	+2·6	−0·2	+1·5	+2·0
Seat 15	+4·5	+2·1	+3·0	+3·1	+2·9	+3·3	+2·0	+2·5	+3·2	+3·7	+3·7	+2·6	+2·8	+3·5	+3·0
Seat 16	+1·5	+0·6	−1·0	−0·9	+1·9	+0·3	0·0	−0·5	−0·8	−0·7	+0·7	+0·6	−0·2	+0·5	0·0
Seat 17	+1·0	+2·6	+1·5	+3·6	+3·4	+1·3	+4·0	+2·5	+4·2	+4·7	+0·7	+4·6	+1·8	+4·5	+4·0
Seat 18	+3·0	+3·1	+3·0	+4·1	+4·4	+2·3	+4·0	+3·5	+5·2	+4·7	+2·7	+3·6	+3·8	+5·5	+5·0
Seat 19	−3·0	−0·9	−1·0	+0·1	−0·1	−2·7	−1·0	−0·5	+0·2	+0·7	−2·3	+1·6	−0·2	+0·5	−1·0
Seat 20	+3·0	+2·6	+3·5	+3·1	+3·9	+2·7	+3·0	+3·5	+3·2	+3·7	+1·7	+3·6	+2·8	+3·5	+4·0

been made to estimate the magnitude of the "order" effect.

The other two basic difficulties in the analysis were that:—

(*i*) there were, for certain noises, one or two acoustically "bad" seats in the cinema, and that

(*ii*) since for any one pair of tapes the greatest number of performances was only 44, the treatment of each seat as an individual experiment could not yield the 100 or more subjects required, statistically, to give a result to within ± 1 dB.

These two difficulties were resolved by grouping the seats together in sets, the differences of the weighted mean sound pressure levels of the compared noises being within $\pm 0{\cdot}5$ dB. in each set, *i.e.* in one set this difference would be the design value $\pm 0{\cdot}5$ dB. in another $+0{\cdot}5$ to $+1{\cdot}5$ dB., and in a third $-1{\cdot}5$ to $-0{\cdot}5$ dB., and so on. Any set in which the total number of subjects was substantially less than 100 was then discarded.

Using such a method, the final results were obtained by means of graphs of which an example is reproduced in Fig. 5. Equality being decided by the median value *i.e.* a 50 per cent vote either way, the actual difference on the graph is only 5·2 dB. but, when the differences in the datum levels of the sounds as presented to the subjects are taken into account, this yields a final figure of 10·8.

That is, as tested in this experiment, the Super-Constellation can be allowed to make a physical sound pressure level 11 decibels higher than (*i.e.* twelve times the sound energy of) the Boeing 707/120 before it is adjudged equally disturbing. In that particular instance the judgement was that of a group of 478 members of the public, the physical sound pressure level being measured, of course, by an accurately calibrated r.m.s. laboratory instrument.

It should again be noted that the collected results of Table IV are, for the time being, provisional. In a survey of this sort there are various second order effects (such as the influence of age distribution amongst the subjects) which it is intended to take into account by a more formal and protracted analysis, so that the final results (which nevertheless are not expected to differ significantly from those of Table IV) may not be available for some time.

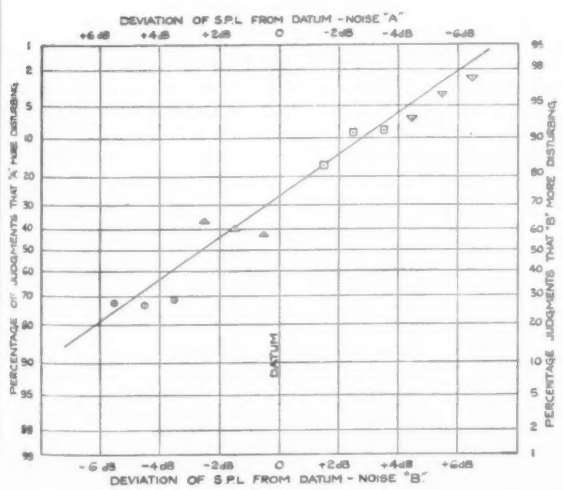

DEVIATION OF S.P.L. FROM DATUM - NOISE "A"
+6dB +4dB +2dB 0 -2dB -4dB -6dB
PERCENTAGE OF JUDGMENTS THAT "A" WAS DISTURBING
PERCENTAGE JUDGMENTS THAT "B" WAS DISTURBING
DATUM
-6 dB -4dB -2dB 0 +2dB +4dB +6dB
DEVIATION OF S.P.L. FROM DATUM - NOISE "B"

FIGURE 5. Disturbance comparison of Boeing 707/120 with Super-Constellation.

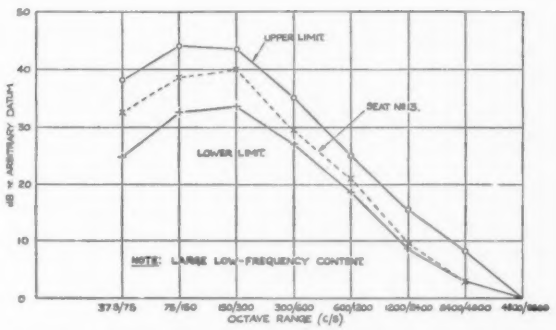


FIGURE 1. Octave band spectrum of noise "*A*" (Super-Constellation) as reproduced in cinema.

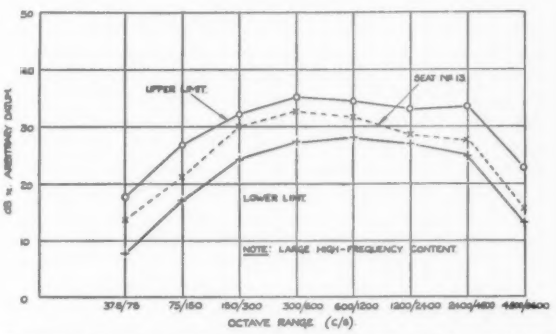


FIGURE 2. Octave band spectrum of noise "*B*" (Boeing 707/120) as reproduced in cinema.

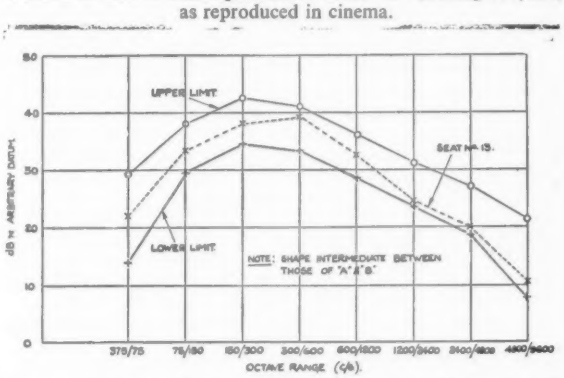


FIGURE 3. Octave band spectrum of noise "*C*" (Vulcan Mk. I) as reproduced in cinema.

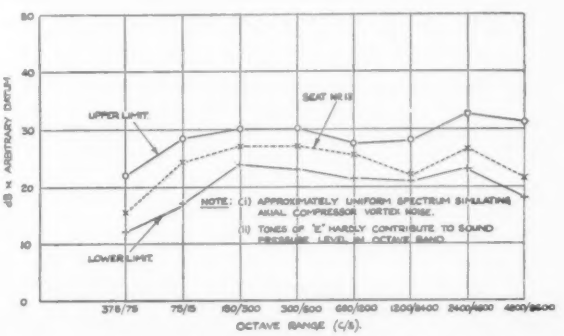

UPPER LIMIT
SEAT NR 13
LOWER LIMIT
NOTE: (i) APPROXIMATELY UNIFORM SPECTRUM SIMULATING AXIAL COMPRESSOR VORTEX NOISE.
(ii) TONES OF "E" HARDLY CONTRIBUTE TO SOUND PRESSURE LEVEL IN OCTAVE BAND.
dB re ARBITRARY DATUM
OCTAVE RANGE (c/s)

FIGURE 4. Octave band spectrum of noises "*D*" and "*E*" (synthetic) as reproduced in cinema.

TABLE IV

THE PROVISIONAL NUMERICAL RESULTS

Noise comparison		$(y-x)$* *at equal loudness*			$(y-x)$* *at equal disturbance*		
Noise x	Noise y	Physical S.P.L.-dB.	Stevens' Phons	Beranek P.N.dB.	Physical S.P.L.-dB.	Stevens' Phons	Beranek P.N.dB.
Super-Constellation	Boeing 707/120	−9·0	−3·1	+0·7	−10·8	−5·1	−1·3
Super-Constellation	Vulcan Mk.I	−4·7	−1·4	+0·7	−6·0	−2·7	−0·6
Vulcan Mk.I	Boeing 707/120	−5·2	−2·6	−0·9	−5·5	−2·9	−1·2
Same by difference of first two lines		(−4·3)	(−1·7)	(0)	(−4·8)	(−2·4)	(−0·7)
Hypothetical aircraft *D*	Hypothetical aircraft *E*	−0·1	−0·4	−0·3	−2·1	−2·4	−2·3

*In the S.P.L. columns, a negative value signifies "louder" (or "more disturbing") for the same S.P.L. In the remaining columns, a negative value signifies that noise y calculates less than noise x (either in terms of Stevens' Phons or P.N.dB.).

It is worth noting at this stage, however, the order of magnitude of the dispersion as illustrated by the slope of the ogive curve of Fig. 5. This corresponds to a standard deviation of 4·4 dB., or taking into account the numbers of listeners, to 98 per cent confidence limits of $\pm 0{\cdot}58$ dB.

Bearing this in mind, the findings of this investigation are, then:—

(*i*) That the original hope of obtaining results accurate to within $\pm 1{\cdot}0$ dB. has apparently been realised: compare lines 3 and 4 of Table IV summarising a "triangular" experiment, the internal consistency of which is within the dispersion.

(*ii*) That the distinction between loudness and disturbance is a fine but valid one: compare the judgements given on the two criteria between the piston-engined aircraft and the two jet-engined machines in lines 1 and 2 of Table IV.

(*iii*) That Beranek's empirical method of subjective noise assessment[3] by the "disturbance" criterion applies reasonably well to comparisons of existing fixed-wing aircraft noises, although it appears slightly to underestimate disturbance—*see* column 6 of Table IV.

(*iv*) That the addition of discrete frequencies to a random noise (for equal overall S.P.L.) has no effect on apparent loudness, but caused it to be judged some 2 dB. more disturbing.

ACKNOWLEDGMENTS

The authors acknowledge the permission of the Chief Scientist, Ministry of Aviation and of the Director of the National Physical Laboratory to publish this note.

REFERENCES

1. FLETCHER, H. and MUNSON, W. A. (1933). Loudness, its Definition, Measurement and Calculation. *Journal of Acoustical Society of America*, 5, 82, 1933.
2. STEVENS, S. S. (1956). Calculation of the Loudness of Complex Noise. *Journal of Acoustical Society of America*, 28, 807, 1956.
3. ANON. (1958). Studies of Noise Characteristics of the Boeing 707/120 Jet Airliner and of Large Conventional Propeller Driven Airliners. Report of Bolt, Beranek and Newman Inc. to the Port of New York Authority, October 1958.
4. BERANEK, L. L., KRYTER, K. D. and MILLER, L. N. (1959). The Reaction of People to Exterior Aircraft Noise. *Noise Control*, 5, 23, 1959.

On Similar Solutions of the Boundary Layer Equations for Air in Dissociation Equilibrium

by

R. L. DOMMETT

(Royal Aircraft Establishment, Farnborough)

NOTATION

a local speed of sound
C_p specific heat of air
D diffusion coefficient (of atoms through molecules in this case)
H total or stagnation enthalpy
i local static enthalpy
Le Lewis number $= \dfrac{\rho D C_p}{\lambda}$
Pr Prandtl number $= \dfrac{C_p \mu}{\lambda}$
T total temperature
t ratio of local temperature to total temperature or local enthalpy to total enthalpy
U transformed local velocity $= \left(\dfrac{i_t}{i_e}\right)^{\frac{1}{2}} u$
u local velocity in x direction
v local velocity in y direction
X transformed x-wise co-ordinate
x distance along surface normal to leading edge
y distance along surface parallel to leading edge
Z transformed z-wise co-ordinate
z distance normal to surface

Received 22nd June 1959.

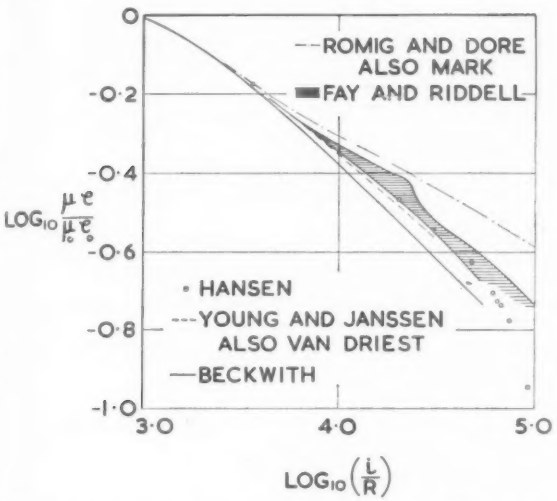


FIGURE 1. Variation of product of viscosity and density with enthalpy from various sources.

γ ratio of specific heats
λ thermal conductivity
μ viscosity
ρ density

Suffixes

e refers to conditions at outer edge of boundary layer
t refers to "total" or stagnation conditions
w refers to conditions at wall
N_t refers to conditions on stagnation line of swept cylinder

Using a Stewartson transformation defined by

$$X=\int_0^x \left(\frac{\mu_w \rho_w}{\mu_t \rho_t}\right)\left(\frac{i_e}{i_t}\right)^{\frac{1}{2}} dx$$

$$Z=\left(\frac{i_e}{i_t}\right)^{\frac{1}{2}} \int_0^z \left(\frac{\rho}{\rho_t}\right) dz$$

it is straightforward to show that in the two cases for which it is possible to find similar solutions to the laminar boundary layer equations with $Pr \neq 1$, $Le=1$, that is stagnation flows $U_e \propto X$ and flat plate flows U_e=constant, it is not necessary to assume anything about the specific heats to derive the equations given and solved by Beckwith[1]. But the following redefinitions are required

t_w formerly $\frac{T_w}{T_t}$ now $\frac{H_w}{H_t}$

t_e formerly $\frac{T_{N_t}}{T_t}$ now $1-\frac{v_e^2}{2H_t}$

and

$$1+\frac{\gamma-1}{2}\left(\frac{u_e}{a_e}\right)^2 \text{ is now } 1+\frac{u_e^2}{2i_e} \text{ etc.}$$

TABLE I

Beckwith[1]	Sutherland μ; constant C_p
Young and Janssen[2] Van Driest[3]	Sutherland μ; variable C_p, no dissociation
Fay and Riddell[4]	Sutherland μ; NBS tables for dissociated air covering 10^{+3} to 10^{-4} atmospheres
Romig and Dore[5] Mark[6]	Krieger and White tables for dissociated air
Hansen[7]	Estimates for dissociated air for 10^{-4} atmospheres

For $Le=1$ the only knowledge of the thermodynamic and transport properties of the gas required therefore is the variation Pr and $\mu\rho$ with i. While it is well known that the Prandtl number of air is little affected by dissociation (in the absence of ionisation) it should be noted that the effect on the variation of $\mu\rho$ is not large either. It must also be remembered that boundary layer characteristics are not sensitive to the variation of $\mu\rho$. Fig. 1 contrasts some different variations that have been used or are available. Table I gives the derivation of each curve.

As Fig. 1 shows that the maximum difference between the variations is only about 20 per cent, even at the edge of a stagnation boundary layer at satellite speeds, it is not surprising that all analyses of stagnation and flat plate boundary layers which ignore diffusion effects agree whether dissociation is considered or not when interpreted in terms of the redefinitions given above.

It is hoped that this provides an explanation of what may appear to be the surprising results of Ref. 8 and a reason for the success of low speed formulae interpreted in terms of enthalpies when applied to boundary layers with dissociation present.

REFERENCES

1. BECKWITH, I. E. (1958). Similar solutions for the compressible boundary layer on a yawed cylinder with transpiration cooling. N.A.C.A. T.N. 4345, September 1958.
2. YOUNG, G. B. W. and JANSSEN, E. (1952). The compressible boundary layer. *Journal of the Aeronautical Sciences*, Vol. 19, April 1952.
3. VAN DRIEST, E. R. (1954). The laminar boundary layer with variable fluid properties. N.A.A. Report AL-1866, 1954.
4. FAY, J. A. and RIDDELL, F. R. (1958). Theory of stagnation point heat transfer in dissociated air. *Journal of the Aeronautical Sciences*, Vol. 25, p. 73, February 1958.
5. ROMIG, M. F. and DORE, F. J. (1954). Solutions of the compressible laminar boundary layer including the case of a dissociating free stream. CONVAIR Report ZA-7-012, August 1954.
6. MARK, R. (1955). Compressible laminar heat transfer near the stagnation point of blunt bodies of revolution. CONVAIR Report ZA-7-016, April 1955.
7. HANSEN, C. F. (1958). Approximations for the thermodynamic and transport properties of high temperature air. N.A.C.A. T.N. 4150, March 1958.
8. BECKWITH, I. E. (1958). The effect of gas properties on the heat transfer in stagnation flows. *Journal of the Aeronautical Sciences*, Vol. 25, p. 533, August 1958.

A Closed Formula for the Drag of a Flat Plate with Transition in the Absence of a Pressure Gradient

by

A. R. COLLAR, M.A., D.Sc., F.R.Ae.S., F.I.A.S.

(*Professor of Aeronautical Engineering, University of Bristol*)

1. INTRODUCTION

Most University students of fluid mechanics are familiar with the problem of the evaluation of the skin friction drag of a flat plate in the absence of a pressure gradient: transition is specified, usually by the free stream velocity and the transition point, or directly by the transition Reynolds number. The solution is normally obtained numerically: so far as the writer is aware, the processes used have not been written down in closed analytical form, though to do so presents no difficulty.

The formula to be given here assumes an instantaneous transition from laminar to turbulent flow, and therefore a definite transition point. Prandtl[1] gives a semi-empirical formula, after remarking that transition occupies a region; Squire and Young[2], however, state that while a transition point may oscillate appreciably if the free stream has turbulence, the transition is so rapid that the concept of a transition point is justified: we accept this here.

2. DERIVATION OF THE FORMULA

Consider Fig. 1: *A*, *E*, are the leading and trailing edges of a plate of chord l. *C* is the transition point, *D* a current point, and *B* the notional leading edge of a plate which in wholly turbulent flow gives an identical turbulent layer from *C* to *E*. The shorter notional plate *BE* is described by Prandtl (*loc. cit*), while Squire and Young (*loc. cit.*) state explicitly Prandtl's implied condition, namely that the momentum thickness must be continuous at *C* since there is no finite impulse on the fluid at that point.

We consider first the laminar layer and write as usual for the momentum thickness at *D*

$$\theta = AxR_x^{-\frac{1}{2}}, \quad . \quad . \quad . \quad . \quad (1)$$

implying

$$R_\theta = AR_x^{\frac{1}{2}}, \quad . \quad . \quad . \quad . \quad (2)$$

and, for a coefficient based on x,

$$C_f\dagger = 2AR_x^{-\frac{1}{2}} \quad . \quad . \quad . \quad (3)$$

Here A is a constant, determined numerically by the profile adopted. For calculation here we use the Blasius value

$$A = 0{\cdot}664. \quad . \quad . \quad . \quad . \quad (4)$$

For the turbulent layer on the notional plate we have similarly

$$\theta = BXR_X^{-1/5}, \quad . \quad . \quad . \quad (5)$$

giving

$$R_\theta = BR_X^{4/5}, \quad . \quad . \quad . \quad . \quad (6)$$

and

$$C_f{}^* = 2BR_X^{-1/5} \quad . \quad . \quad . \quad (7)$$

Received 2nd October 1959.

For B we use the number stated by Prandtl to agree best with experiment, namely

$$B = 0{\cdot}037. \quad . \quad . \quad . \quad . \quad (8)$$

Now from Fig. 1

$$X = x - a,$$

or

$$R_X = R_x - R_a, \quad . \quad . \quad (9)$$

and substitution in (6) gives

$$R_\theta = B\,(R_x - R_a)^{4/5} \quad . \quad . \quad . \quad (10)$$

At the transition point we write $R_x = R_C$; then since θ (and therefore R_θ) is continuous across *C*, we have from (2) and (10)

$$AR_C^{\frac{1}{2}} = B\,(R_C - R_a)^{4/5},$$

whence

$$R_a = R_C - \left(\frac{A^2R_C}{B^2}\right)^{5/8} \quad . \quad . \quad . \quad (11)$$

Finally, the drag coefficient for the whole plate, based on the chord l, is given by (writing R for R_l):—

$$C_f = \frac{2\theta\,(l)}{l} = \frac{2R_\theta\,(l)}{R},$$

and on use of (10) and (11) this gives

$$C_f = \frac{2B}{R}\left\{R - R_C + \left(\frac{A^2R_C}{B^2}\right)^{5/8}\right\}^{4/5} \quad . \quad . \quad (12)$$

3. COMMENTS ON THE FORMULA

With the numerical values given by (4) and (8), equation (12) becomes

$$10^3C_f = \frac{74}{R}\left\{R - R_C + 36{\cdot}9\,R_C^{5/8}\right\}^{4/5} \quad . \quad (13)$$

The corresponding result for purely laminar flow, obtained from (13) with $R_C = R$, or directly from (3), is

$$10^3C_f\dagger = 1328\,R^{-\frac{1}{2}}, \quad . \quad . \quad . \quad (14)$$

while for fully turbulent flow we obtain from (13) with $R_C = 0$, or from (7),

$$10^3\,C_f{}^* = 74\,R^{-1/5}. \quad . \quad . \quad . \quad (15)$$

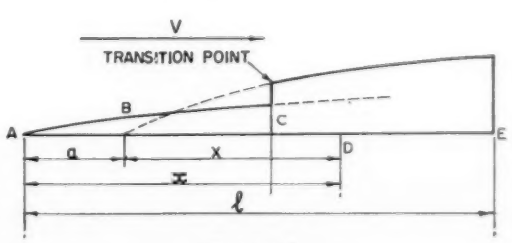


FIGURE 1.

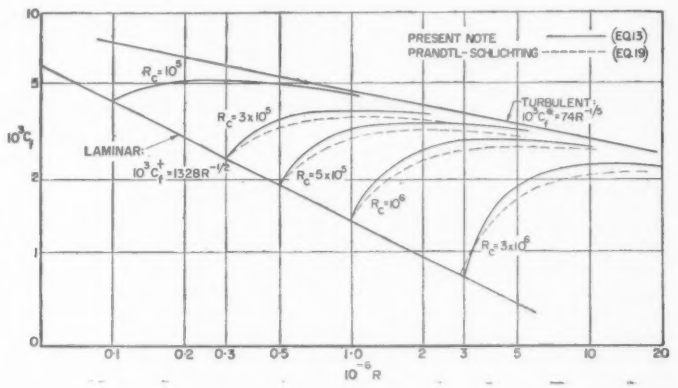


FIGURE 2. Values of C_f.

In view of (13) and (15) it is possible to write

$$C_f=C_f^*\left\{1-\frac{(R_C-36{\cdot}9\,R_C^{5/8})}{R}\right\}^{4/5} \quad . \quad (16)$$

The relations (14) and (15) are shown in Fig. 2 in the usual logarithmic plot. Also drawn are the curves (13) for a range of transition Reynolds numbers R_C.

4. THE PRANDTL-SCHLICHTING FORMULA

Prandtl (*loc. cit.*) obtained a formula as follows: he compares "two flows (1) when the flow commences by being laminar and becomes turbulent only after a definite Reynolds number . . . . is reached and (2) when turbulent flow occurs immediately at the leading edge . . . . the plate in (1) is longer than the plate in (2) . . . . to ensure the same value of the resistance." He then remarks that since the drags are equal,

$$lC_f=(l-a)\,C_f^*$$

in our notation; hence

$$C_f=C_f^*\left(\frac{R-R_a}{R}\right) \quad . \quad . \quad . \quad . \quad (17)$$

So far, this is wholly in accord with the analysis of the present note; in particular, we may observe in passing that since Prandtl's C_f^* in (17) is based on the chord $(l-a)$, the equation may be written, in view of (7) and (9)

$$C_f=\frac{2B}{(R-R_a)^{1/5}}\left(\frac{R-R_a}{R}\right)$$

which is equivalent to (12), though R_a is undetermined. Prandtl, however, did not pursue the analysis beyond (17): he states (*see* Section 1) that transition occupies a region, thus implying the indeterminacy of R_a. In view of this he then gives the empirical formula

$$C_f=C_f^*-\frac{1700}{R} \quad . \quad . \quad . \quad . \quad (18)$$

This formula, he says, fits the facts well, though "it is not possible to deduce it from theoretical considerations." It is important to note, if (17) and (18) are compared, that in (17) C_f^* is based on the chord $(l-a)$ and in (18) on the chord l. The relation (18) is in fact not seriously in error for a transition Reynolds number $R_C=5\times10^5$; the relation is shown dotted in Fig. 2.

Schlichting[3] attempts a derivation and extension of Prandtl's formula, to take account of variation in R_C. In relation to the change in drag coefficient, he says ". . . . the decrease can be estimated if it is assumed that behind the point of transition the turbulent boundary layer behaves as if it were turbulent from the leading edge. Thus from the drag of a wholly turbulent boundary layer it is necessary to subtract the turbulent drag of the length up to the point of transition . . . . and to add the laminar drag for the same length." From this hypothesis he is able to deduce the result

$$10^3C_f=\frac{74}{R^{1/5}}-\frac{K\,(R_C)}{R}, \quad 5\times10^5<R<10^7 \quad . \quad (19)$$

where $K\,(R_C)$ is related to R_C as follows:—

$10^{-6}R_C$	0·3	0·5	1	3
$10^{-6}K$	1·05	1·7	3·3	8·7

The second entry makes (19) agree with Prandtl's empirical formula (18). However, while Schlichting states plainly that he is making an assumption, his hypothesis is clearly at variance with Prandtl's notional shorter plate, and the momentum thickness will therefore not be continuous at transition, implying an impluse on the plate. Thus the hypothesis is really inadmissible, and it would be better to regard (19) as empirical rather than analytical, especially as it gives results not very different from (13). From Fig. 2 it will be seen that (19) corresponds to a slight increase of R_C with R, or in general gives rather too small a value of C_f for given R and R_C.

It would appear to the writer (who is obviously biased) that not only is (13) based on a sounder analysis than (19); it is just as easy to evaluate numerically.

REFERENCES

1. PRANDTL, L. (1934). *The Mechanics of Viscous Fluids.* Durand, Vol. III, Sect. G., pp. 151-2, January 1934.
2. SQUIRE, H. B. and YOUNG, A. D. (1937). The Calculation of the Profile Drag of Aerofoils. R. & M. 1838, November 1937.
3. SCHLICHTING, H. (1955). *Boundary Layer Theory.* Pergamon Press, Ch. XXI, p. 434, 1955.

Safety in Relation to Structural Failure

A. H. CRAWSHAW, A.F.R.Ae.S.
(*Blackburn Aircraft Ltd.*)

IT IS being accepted in aeronautical circles that "fail-safe" structures may be allowed to continue to fly with fare-paying passengers after cracks have been discovered which reduce the specified strength of the aeroplane. Arguments have been produced to show that the permissible reduction in strength after cracking may be considerable and even that, if the structure is "fail-safe," its weight can be reduced. These arguments are fallacious and dangerous; they are based on the probability of an aircraft crashing during its life.

It is suggested that the criterion should be:—the probability of a single passenger being killed during any hour of a flight.

This probability of being killed must not be allowed to increase beyond an agreed amount which should be published by the Airworthiness Authorities.

Civil aircraft are designed to withstand (with a factor of 1·5) a 66 ft./sec. up-gust when flying at a low speed. Greater up-gusts can be encountered and the flying speed may be higher. Aircraft have been almost wrecked in bad weather; and how many have been completely wrecked we do not know, possibly a fair proportion of those which have disappeared without trace.

We cannot therefore claim to have excessive margins. Now if the existing standards are just acceptable we must not reduce them.

Referring to Mr. A. E. Russell's paper "Safety in Relation to Structural Damage" presented at the Sixth Anglo-American Conference in 1957 (published by the Royal Aeronautical Society, 1959):—

Figure 3: An aircraft with full strength can be expected to fail on the average in 10^7 hours. It it has only 66 per cent of this strength it can be expected to fail in 4×10^4 hours, *i.e.* the risk of failure in any one hour is 250 times as great.

Mr. Russell states in Section 3 (p. 238):—

"At any time between inspections, the damaged structure must be as safe in relation to the probable loads expected to occur in this limited period, as the undamaged structure is in relation to the loads expected to occur within the whole lifetime of the aircraft."

Mr. Russell is here considering the chances that the aircraft will crash during its life. We are not concerned with the lifetime of the aircraft but with the lifetime of the passengers. It is obvious that the risk to the passenger during one hour's flight in a cracked aeroplane is greater than the risk of flying for one hour in an uncracked one; 250 times as great!

Even the risk of the aircraft crashing during its working life has been increased by very nearly 2, as there is the risk during the whole period of its normal life (uncracked or repaired) plus the equal risk that has been taken for the short cracked period.

The same risk of the aircraft crashing during the whole of its life, which would be shared by all the passengers who fly in that aeroplane during its life, is being imposed on the unfortunate individuals who are passengers during the short time that it flies cracked. The criterion proposed would seem to be analogous to Dr. Lundberg's maximum permissible failure rate.

Received 21st September 1959.

A crack may appear in an old aircraft in a thunderstorm. The weather may continue bad and probably will not immediately return to average, as is usually tacitly assumed, *i.e.* the risk of further damage is high.

Some of the results of accepting the proposed criteria would be:—

(*i*) Aircraft would have the necessary strength after cracking and hence would be stronger to start with and therefore probably heavier.

(*ii*) The aircraft would be up to standard during the last hour of its service life. The standard of safety near the beginning of its life would be greater but this is irrelevant.

(*iii*) The risks to a passenger will be the same whether he flies in a large aeroplane or a small one or whether it is full or whether he is the only passenger. (Provided the weight is made up with cargo.)

REPLY

by

DR. A. E. RUSSELL, C.B.E., D.Sc., F.R.Ae.S., F.I.A.S.
(*Director and Chief Engineer, Bristol Aircraft Ltd.*)

THE ACCEPTANCE of the fail-safe approach to aircraft structural design does not imply any reduction in the safety standards currently used. Should some structural damage be discovered which results in a reduction in strength, then the aircraft should be immediately repaired. If there is a known reduction in strength, and if the damage is known to be of a non-propagating nature, then it would be perfectly reasonable to operate the aircraft at reduced speeds and weights appropriate to the reduced strength. It is unlikely that this would normally be done, but it is technically justifiable.

The main objective of the fail-safe approach is to protect the aircraft against the consequences of damage while it is still undiscovered. Flight in the aircraft during this period must inevitably be less safe but the designer is trying to guard against a situation in which a purely safe-life aircraft would already have failed. In a perfect world the problem would not arise, the reasons why it does arise are discussed at length in my paper given at the Sixth Anglo-American Conference.

In applying statistical processes to the assessment of fatigue lives of structures, the engineer uses mathematical calculations which lead to virtually negligible risks. He has to make assumptions about the statistical distributions of fatigue results which he knows are not exactly true, but which experience has shown to serve his purposes very well. The publication of risk levels is therefore not practicable; the intending passenger must judge for himself.

The object of applying statistics to the damaged structure in my paper, was to try to get some measure of the problem of providing a negligible risk level during a possible period of undiscovered damage. The details admit of much argument but if the objectives and limitations of the calculations are borne in mind they should be of some value.

Graduates' and Students' Section

The Aerodynamics of Racing Cars

The interest the section shows in motor cars was forcefully demonstrated by the large number of members who attended the lecture on Wednesday 2nd December 1959. The lecture, on the Aerodynamics of Racing Cars, was given by Mr. Frank Costin, perhaps the foremost authority on this application of Aerodynamics.

The lecturer began by clarifying his own situation by saying that he regarded himself primarily as an aircraft engineer. His flair obviously being minute observation, must have been a strong influence in his success both in the Aircraft Industry and later in connection with racing cars. He outlined his introduction to car design by saying how uninteresting he found motor racing until he met Colin Chapman, who was intent on producing a car which would take everything to the *n*th degree. Chapman required Costin to produce an enveloping body of minimum drag and neutral stability, but the greatest problem was that of providing cooling air for the engine, oil, brakes and driver. His approach to the low drag requirement was to remove all external fitments possible and to enclose as much of the rest as possible. As a result, the Lotus Mk VIII had large fins, a metal tonneau, retractable headlight and a C_D well below previous comparable cars. After this he mentioned how this C_D (based on frontal area) was progressively reduced from 0·4 on the Mk VIII to 0·33 on the Mk XI and then to 0·29 on the record-breaking Mk XI.

The lecturer had plenty to say about the effects of "styling" on the drag of many production cars today and mentioned the detrimental effect this has on fuel consumption, particularly when one considers roads such as the M.1.

There were a large number of questions asked which raised problems varying from the drawing of brake cooling air via the cockpit depression to the drag incurred by having exposed wheels.

The lecturer did not endeavour to set out the problems mathematically; he gave a very interesting informal account of the practical way in which he sets out to overcome the aerodynamic problems of cars.

Although Mr. Costin has been consulted by such concerns as Vanwall, Maserati, Lister and Lotus, he still feels that the art of car aerodynamics has progressed little further than the Wright Brothers knowledge of aircraft aerodynamics in 1903.—A.R.M.P.

Visit to A.E.R.E. Harwell

The Establishment was visited on Saturday 21st November 1959 by a party of twenty strong who spent an enthralling afternoon getting a glimpse of the work carried out in this, the main research unit of the Atomic Energy Authority.

About three-quarters of the effort of the five or six thousand people employed is directed towards fundamental research into the design and use of various types of reactors. The rest of the effort is taken up by the production of radio-active isotopes, the handling and processing of radio chemicals, and various other studies.

We were first introduced to the fundamentals of atomic reactors by a colour film "The Principles of Nuclear Fission" shown in the impressive lecture theatre of the Cockcroft Hall—designers of the R.Ae.S. Lecture Hall please note!

The party now split into three groups each with a guide and attended, with sheepdog-like persistence, by a Security Officer. It was explained later that his presence was mainly to ensure that none of the party got lost, and that there were no doubts cast on our allegiance.

The writer's party visited first the isotope handling division where the "hot" compounds produced in the reactors are packed for transit all over the World. Usually this is done by remote control behind a lead brick wall and contamination risks are kept negligible throughout packing and transit.

We also saw examples of the uses to which isotopes are put in the industrial, chemical and medical fields. For instance, foodstuffs sterilised by a short exposure to radiation keep almost indefinitely. This sterilisation does no harm to the food; it does not become radioactive itself.

We next visited the famous ZETA, which is at present being re-built to investigate some of the problems it uncovered in its search for fusion power. It was made obvious to us that this apparatus is very far from being the failure that the popular Press seem to think it is.

Finally, we visited the BEPO pile. This is an air-cooled, graphite moderated reactor using uranium 235 fuel, first operated in 1948.

Now, it produces a steady stream of isotopes, and has provided the basis of design and operation for all the Electricity Authority's large power producing stations. Further research into reactor design is proceeding in this and other reactors.

Throughout the Establishment it was impressive to see the elaborate safety precautions taken to prevent contamination. Monitors for radiation are at the door of every laboratory and all the systems are as foolproof as possible.

It is difficult in this space to do adequate justice to this pleasant and informative visit and much of the credit for this is due to the expert knowledge of our guides, to whom we tender our grateful thanks.—A. H. F.M.

Professional Status of Members

Dear Sir—The correspondence in recent editions has focused attention again on the extraordinary situation regarding recognition of professional status of members of the Society by outside sources.

Although your correspondents have rightfully drawn attention to the reluctance of aircraft firms, etc., to recognise the professional status of members of what is really their own professional Society, the situation is perhaps more aggravated in technical and further education. It may not be generally known that the Burnham Report does not recommend any grade of membership of the Society for purposes of incremental additions to salary. Indeed an examination of the Report shows that practically every known professional qualification of this country (and some not so well known) carry incremental salary additions.

I have requested the Society to represent the Society's views on this matter and I have been informed that this the President has done but the Burnham Committee have not made further recommendations. I would suggest that a further approach might be made.

Yours faithfully,

C. T. KIMBER,

17th November. Wing Commander (Rtd.)

Future Visits

Visits have been arranged on Saturday 30th January at 9.30 a.m. to Sir W. G. Armstrong Whitworth Aircraft Ltd., at Baginton and on Wednesday 24th February at 2 p.m. to the Ford Motor Co. Ltd., at Dagenham.

Applications should be made to the new Hon. Visits Secretary: N. R. Craddock, 5 Oxleay Road, Harrow, Middx.

This page is a new venture for the JOURNAL, *and reflects the growing awareness of the work done in the Branches. The decision to give space was warmly welcomed by the recent Branches Conference, and this "first edition" hopes to portray a brief historical survey which can be amplified in later editions. Current news will also be our concern.*

IT WAS IN 1917 that the Council of the then Aeronautical Society decided that it could not fully attain its objects by holding all its functions and lectures in London. It announced that it proposed, if possible, to form graduate branches of the Society in South Farnborough, Hendon, Glasgow and Manchester. Branches were formed in Manchester and Hendon during 1918-1919, the Manchester Branch arranging through the University of Manchester for a course of aeronautical lectures. Little is known of the history of the Hendon Branch although it is reported that successful meetings were held. It is clear that the Council was impressed by the success of these two Branches and appealed in the Annual Report in 1918 for additional Branches to be formed. As a result more Branches were formed, one of which was at Cape Town, although this was only active for a brief time at the end of the war.

In 1919 the Scottish Branch, arising from the projected Glasgow Branch, was formed and was centred at Glasgow with sub-centres at Edinburgh, Aberdeen and Dundee. That it was immediately successful is shown by the fact that it had 156 members in 1920. The formation of this Branch was largely due to the enthusiasm of the Rt. Hon. Lord Weir of Eastwood who was President of the Society from 1919 to 1926, and his organisation was rather similar to the present Divisions in that the Scottish Branch collected the subscriptions from the members on its rolls and remitted to the Main Society fifty per cent of these fees. Fellows and Associate Fellows were elected by the Council in London but members and Associate members were elected by the Scottish Executive Committee, and courses of lectures in aeronautics were arranged at Glasgow University, at Edinburgh and at Dundee University College. The Scottish Branch in all ways acted like the Main Society in London and continued active, although with waning enthusiasm until 1926, when the Executive Committee reported that before the end of the year their funds would be exhausted. (In 1920 the first affiliation of an existing Aeronautical Society to the Main Society had been made when the Cambridge University Aeronautical Society, a branch of their Engineering Society, was affiliated to the Society.)

In the meantime, an entirely new conception of Branches had been developed by Captain J. L. Pritchard, who became Honorary Secretary of the Society in 1925, when the Council issued a note covering the proposed extension of activities of the Society. It was proposed to do as much as possible to enable members of the Society not resident in London to enjoy the benefits of metropolitan members. The scheme was, in fact, one framed both to attract membership to the Society and to help its then existing membership. To quote from the original report—"to give similar facilities to those living in other parts of the country it has been suggested that local Branches should be formed in areas so selected as to include centres of activity within reasonable distance".

This suggestion for local Societies was discussed and agreed. Captain Pritchard immediately started to prepare a draft Branch constitution, which was issued in 1926 and was sensibly the same as that now existing. The Society granted autonomy to the Branches and gave the local Committee the right to enrol Branch Members unable to join the Main Society. It is this right which differentiates our Branches from those of any other learned Society.

The first Branch formed under the new arrangement was Coventry in 1926, and the inaugural lecture was read by Mr. W. S. (now Sir William) Farren.

The second to be formed was Yeovil when in 1926 the Westland Aircraft Society was affiliated as a Branch.

In 1927, the Leeds Branch was formed and was quickly followed by Halton, mainly connected with the Halton Aero Club. Although this original Halton Branch did not run continuously for many years, because of the difficulties arising from a constant change in membership and the original Branch eventually had to be closed, the Council approved the formation of a further branch at Halton built on a rather firmer foundation with outside members.

The Manchester Branch was active in 1927 and a Branch in Australia, formed as a Branch of the Institution of Aeronautical Engineers, was also founded in that year. By the time of the 63rd Annual Report of the Council in 1928 there were six Branches operating with a total membership of 2,844, an increase of 1,900 over the year, although admittedly, of this total 1,500 were members of Halton. Today, the Branch membership is 7,498. During 1928 an inaugural meeting was held of the Oxford Branch, which was connected mainly with the Oxford University Air Squadron. Unfortunately, it did not have a long life.

The Bristol Branch was formed in 1929, and with the great support of the Bristol Aeroplane Company, is now the second largest Branch.

1930 saw the opening of the Gloucester and Cheltenham Branch and the closing of the original Halton Branch for service reasons. Gloucester and Cheltenham, with its dual personality, acted as a prototype for the extension of the Leeds Branch to cover Hull, which was some six years later to effect a compromise and call itself the Brough Branch. 1930 saw a further extension of the Society's Branches overseas. Captain Pritchard visited Canada and America and following his visits, Branches of the Society, working closely with the Engineering Institute of Canada, were formed at Montreal and at Ottawa.

The years 1930 to 1934 were difficult times for the Branches as indeed they were for many other bodies but 1935 was the beginning of a new effort. The Southampton and Portsmouth Branches were formed and all the original Branches maintained and increased their activity.

In 1937 the Weybridge (now the largest) and the Isle of Wight Branches joined the growing movement and in 1938 began Belfast and Medway, some 400 miles apart which, following the war, were to become one with the move of Short Bros. At the beginning of hostilities there was almost a complete halt in the Branch movements, but once matters became more settled early in 1943, many again became active and, in fact, three new Branches at Birmingham, Glasgow and Derby were approved by the Council during 1944.

In 1944 the Council, studying its activities for the immediate post-war years, decided to form for the first time a Branches Committee, to ascertain what the Society

Branch	Date of Formation	Total Membership Oct. 1959	Society Members	Memorial Lectures	Date of 1st Lecture
Belfast	1938	209	89		
Birmingham and Wolverhampton	1944	72	31		
Boscombe Down	1953	432	51		
Bristol	1929	671	331	Barnwell Memorial Lecture	1954
Brough	1928	589	202	Sir George Cayley Memorial	1954
Cambridge	1957	139	27		
Chester	1950	228	24		
Christchurch	1956	163	58		
Coventry	1925	404	243		
Derby	1941	293	186	Sir Henry Royce Memorial	1956
Glasgow	1944	130	35	Pilcher Memorial	1956
Gloucester and Cheltenham	1930	410	129		
Halton	1950	263	16	Trenchard Memorial	1958
Hatfield	1938	459	132	Halford Memorial	1959
Henlow	1952	246	57	Trenchard Memorial	
Isle of Wight	1937	173	67		
Leicester	1945				
London Airport	1956	390	137	Fairey Memorial	1959
Luton	1942	164	61		
Manchester	1927	266	86	Chadwick Memorial	1956
Merthyr Tydfil	1952	70	11		
Preston	1947	298	64		
Reading	1945	178	53		
Southampton	1935	152	83	Mitchell Memorial	1954
Southend	1956	58	11		
Swindon	1956	121	91		
Weybridge	1937	884	380	R. K. Pierson Memorial	1952
Yeovil	1926	281	71	Stringfellow Memorial	1956
Singapore	1953				
TOTAL		7498	2619		

could do to assist its Branches. Already the Branches were a national movement assisting the Society to fulfil its objects. A meeting of Branch Chairmen and Secretaries was convened in January 1945 and so the Branches were brought together for the first time, when Council announced that to encourage the participation of Main Society members in Branch affairs, they had agreed to pay the Branch subscriptions of all Main Society members. Major Shilson was the first Chairman of the Branches Committee and later in 1945 he again called the Branches together to discuss their future. It was at this meeting that the Branches unanimously turned down the suggestion that Branches of the Society should be restricted to members of the Society and thus confirmed their agreement of the original ideas of the Branches.

Over this period of reorganisation, three new Branches had been formed—at Reading, Leicester and in New Zealand—and the Hatfield Branch, which had been formed in April 1939 and converted into an Engineering Society for the period of hostilities, was reformed in 1946. South Africa also formed a Branch in 1946 at Johannesburg. With the inter-change of information which followed automatically from the Branch Conferences, many of the Branches extended their activities. In fact, the Branches began to act as small units of the Society.

The next major step which was taken in the relations between the Branches and the Main Society was the establishment from 1948 of Main Society Lectures held at the Branches. The first was read at Birmingham, and these have now been given at all branches. They are most successful and have become some of the most highly attended lectures of the Main Society. In 1949, the Society started a new experiment, when the Australian, New Zealand and South African Branches were turned into Divisions, with rights to form their own Branches.

It was not until 1950 that two further names were added to the growing movement in this country, Halton and Chester.

Following the resuscitation of the Halton Branch, Henlow (at the R.A.F. Officers Training Centre) followed in 1952 and the first representation from Wales was that of Merthyr Tydfil. Since 1952, we have been joined by Boscombe Down, Cambridge, London Airport, Southend and Swindon. An overseas name to add to the list is Singapore.

This brief survey has tended to telescope the past few important years, but whereas recent history is possibly well known and its importance appreciated, that of the pre-war period is unknown to many.

Both from its Members and in its activities, much of the Society's work is in the Branches (as in all healthy trees) but this "first edition" hopes to do more than merely outline the past. Attention is drawn to the Table which shows that there are now very few centres of aeronautical activity in this country that have no nearby Branch. From this comes the rather surprising fact that of a total Society Membership of 10,723, only some 2,700, or approximately 28·4 per cent are Members of a Branch. These figures can only be approximate because the figures for the Leicester and the Singapore Branch are not known.

As a reader of this Journal, you will be a Member of the Society—but have you joined your local Branch? They have much to offer—the subscription is very small, and for many is entirely free.

". . . . and the green grass grew all around."—G.W-W.

Seventh Anglo-American Aeronautical Conference

New York — October 1959

FOR the second time in the history of the joint I.A.S.-R.Ae.S. Conferences British and American delegates met together in New York to discuss problems of current interest in the aeronautical industries on both sides of the Atlantic. Some of the problems discussed this year may not have been even dreamed of in 1949 but, if the problems were different, the renowned hospitality of the American people had not changed, and from 4th October until 16th October the 75 British delegates, 25 of whom were accompanied by their wives, were made to feel at home by a host of friends, new and old, in both the United States and Canada.

For the first time, the Canadian Aeronautical Institute was invited to join the Conference and two of the papers read at the technical sessions were contributed by Canada; thirty-five members of the C.A.I. were present during the sessions in New York, and the British delegates and their ladies spent three very pleasant days in Canada. The Seventh Anglo-American Conference delegates quite literally covered much ground by beginning in New York and ending in Toronto, twelve days and some hundreds of miles later.

The British delegates arrived in New York by sea and by air, the largest number by B.O.A.C.'s Comet services on Saturday 3rd October. They all converged on the Conference Headquarters, the Hotel Astor in Times Square, on 4th October for the opening reception given by the President, the Officers and the Council of the Institute of the Aeronautical Sciences. This gave the British party an opportunity to renew old friendships and to make new ones before the more serious business of the technical sessions began on the following day.

During the afternoon British delegates had registered, collected copies of all but three of the 21 papers (two were available later), checked on the field trips they were to make and had received a handsome navy blue plastic case large enough to hold all their papers, invitations, tickets, time-tables and brochures. The ladies received an attractive scarlet writing case.

THE LECTURES

The technical sessions were formally opened with speeches by the Presidents of the I.A.S. and R.Ae.S., Mr. William Littlewood and Mr. Peter G. Masefield, on the Monday morning. Unfortunately, Dr. D. C. MacPhail, President of the C.A.I. was unable to be present at the opening session, but for the first time the Secretary of the Canadian Aeronautical Institute, Mr. H. C. Luttman, was on the platform with officials of the Institute and of the Society. From the Monday to Wednesday (5th-7th October) the delegates had a choice of lectures as sessions were run simultaneously in the North and East Ballrooms on the eighth floor of the Hotel Astor.

The Lecture Programme was as follows:—

5th October

MORNING

Chairman: W. Cawood, Deputy Controller, Aircraft Research and Development, Ministry of Supply.

Instrumentation for Space Science Research. John W. Townsend, Jr., Assistant Director, Goddard Space Flight Center, N.A.S.A.

Chairman: A. M. Freudenthal, Professor of Civil Engineering, Columbia University.

Aircraft Fatigue—A Survey of Current Thought. R. J. Atkinson, Head, Structural Fatigue Division, Structures Department, R.A.E.

AFTERNOON

Chairman: H. Guyford Stever, Associate Dean of Engineering, M.I.T.

The three Presidents: from *left to right* Mr. William Littlewood, I.A.S., Dr. D. C. MacPhail, C.A.I. and Mr. Peter G. Masefield, R.Ae.S.

Recent Studies of Satellite Orbits. E. C. Cornford, D. G. King-Hele and R. H. Merson, Guided Weapons Department, R.A.E.

A Study of Stability and Control Characteristic of Atmosphere-Entry Type Aircraft Through Use of Piloted Flight Simulators. Brent Y. Creer, D. R. Heinle and Rodney C. Wingrove, Aeronautical Research Engineers, Ames Research Center, N.A.S.A.

Chairman: Dr. E. S. Moult, Technical Director, de Havilland Engine Co. Ltd.

The Technical Development of the DHC-4 Caribou Utility STOL Aircraft. R. D. Hiscocks, de Havilland Aircraft of Canada Ltd.

Engines for VTOL Aircraft. H. Pearson, Chief Research Engineer, Rolls-Royce Ltd.

6th October

MORNING

Chairman: A. R. Collar, Professor of Aeronautical Engineering, University of Bristol.

The Behaviour of Supersonic Boundary Layers in the Presence of Shock Waves. G. E. Gadd and D. W. Holder, National Physical Laboratory. (The lecture was read by Dr. N. Curle of the National Physical Laboratory, in the unavoidable absence of the authors.)

Hypersonic Separated Flows. S. M. Bogdonoff, Professor of Aeronautical Engineering and Head, Gas Dynamics Laboratory, and Irwin E. Vas, Research Associate, James Forrestal Research Center, Princeton University.

Chairman: David S. Little, Superintendent, Dev.-Navigation Aids, American Airlines.

The Work of the Blind Landing Experimental Unit. W. J. Charnley, Superintendent, Blind Landing Experimental Unit, R.A.E.

Blind Take-Off and Landing Considerations for Present and Future Aircraft. Nelson C. Harnois, Division Engineer, Electronic and Armament Systems; and G. H. Stocker, Electronic Systems Engineer "A", Electronic and Armament Systems Engineering Department, Lockheed Aircraft Corporation.

AFTERNOON

Chairman: M. B. Morgan, Scientific Adviser, Air Ministry.

Design Philosophy for High Acceleration and Temperature. Bernard O. Heath, Assistant Chief Engineer, English Electric Aviation Ltd.

Interactions Between the External Flow and Rocket Exhaust Nozzle. Carl F. Schueller, Chief, Propulsion Aerodynamics Division, Lewis Research Center, N.A.S.A.

Chairman: Courtland D. Perkins, Chairman, Department of Aeronautical Engineering, Princeton University.

The Future of Automatic Control on Fixed Wing Aircraft. Professor G. A. Whitfield, College of Aeronautics, Cranfield.

Flying Qualities Associated with Several Types of Command Flight Control Systems. Sigurd A. Sjoberg, Aeronautical Research Engineer, Langley Research Center, N.A.S.A.

7th October

MORNING

Chairman: E. T. Jones, Deputy Controller, Overseas Affairs, Ministry of Supply.

Re-entry Studies in Free-Flight Ranges. G. V. Bull, Superintendent, Aero Physics Wing, Canadian Armament Research and Development Establishment.

Ablation in Hypersonic Flows. Lester Lees, Professor of Aeronautics, Guggenheim Aeronautical Laboratory, California Institute of Technology.

Chairman: Dr. T. P. Wright, Vice-President, Research, Cornell University.

Unresolved Civil Airworthiness Problems. Walter Tye, Chief Technical Officer, Air Registration Board.

Research and Development Programme for Future Air Traffic Control Systems. Captain Alden C. Packard, U.S.N., Acting Director of Research and Development, Federal Aviation Agency.

AFTERNOON

Chairman: W. R. Sears, Director, Graduate School of Aeronautical Engineering, Cornell University.

Some Considerations of Shape and Control for Hypersonic Flight. Hugh Metcalfe, Chief Aerodynamicist, Bristol Aircraft Ltd.

Thermodynamics and Heat Flow Analysis by Lagrangian Methods. M. A. Biot, Research Consultant.

Chairman: Sir A. H. Roy Fedden, Aeronautical Consultant, Dowty Group Ltd.

Similarity and Flight Simulation in Hypersonic Test Facilities. A. H. Flax, Vice-President, Technical Operations, Cornell Aeronautical Laboratories.

Films—Introduction by E. L. Bass, Technical Manager, Aviation Division, Shell International Petroleum Company Ltd.

Against the lights of Broadway; Mr. Littlewood and Mr. Peter Masefield on their way to the Conference Dinner.

All the slides used by the British lecturers had been prepared by Bristol Aircraft Ltd., to ensure that they were to a standard pattern; all made full use of colour, and they were clear and easy to read.

Lectures were followed by discussion periods, often disappointingly short and, in one or two cases, there was no discussion. But if the formal discussions were brief, delegates found opportunities for informal discussions during the lunch breaks and in the evening.

Lunch for the delegates was served each day in the Emerald Room at the Astor and here American hospitality was again evident, all the British delegates being guests of various American firms.

While their husbands were attending the lectures, the British wives were well entertained. An American Hostess Committee had drawn up such an exciting programme of sightseeing trips and other excursions that many delegates were heard expressing the wish to "borrow a skirt" and join the ladies. The trips included a circular tour round Manhattan Island by boat, a visit to the United Nations building with lunch in the Delegates Dining Room, and a visit to a Television Studio. Also, to make the ladies feel thoroughly at home, afternoon tea was served for them in the I.A.S. suite at the hotel every day.

Informal discussions among delegates between technical sessions in the Astor Hotel.

THE CONFERENCE DINNER

The technical sessions in New York ended with the Conference Dinner at the Hotel Astor on Wednesday 7th October. This was attended by about 400 delegates and guests and was the occasion for the presentation of the Elmer A. Sperry Award for 1959 to the de Havilland Aircraft Company Ltd. for "the vision, courage and skills displayed in conceiving, developing and producing, the world's first jet-powered passenger transport"—the Comet. Cited in the award were Sir Geoffrey de Havilland, Mr. C. C. Walker and the late Major F. B. Halford. Unfortunately, neither Sir Geoffrey nor Mr. Walker could be present

because of ill health, but the award was accepted on Sir Geoffrey's behalf by Sir Aubrey Burke, Chairman and Managing Director of the Company and on Mr. Walker's by Dr. E. S. Moult, Technical Director, de Havilland Engine Co. Ltd.; Major Halford's daughter, Mrs. John Draper, was present to acknowledge her father's citation, and Mr. I. S. Fossett, President of de Havilland Aircraft Inc. accepted the award on behalf of the de Havilland employees. The presentations were made by Dr. T. P. Wright, Chairman of the Board of Cornell Aeronautical Laboratory, Inc. and Vice-President, Research, of Cornell University.

Before the Award was made, the delegates and guests had been welcomed in a speech by the I.A.S. President, Mr. William Littlewood, who drew attention to the battle-scarred Union Jack hanging above the top table, recalling that this was the flag that had flown above the R.Ae.S. building throughout the war and had been presented to the I.A.S. in 1945.

In his reply to this speech, the President of the R.Ae.S., Mr. Peter G. Masefield, expressed the gratitude of all the British delegates and their ladies for the hospitality they were receiving and invited the members of the I.A.S. to attend the Eighth Conference in England in 1961.

PLANT VISITS

Early on the morning of the 8th October, having had little time to recover from the effects of technical sessions and the Conference Dinner, the British delegates embarked on their programme of plant visits. The full programme of these visits was as follows:—

8th October—by air to:
The Glenn L. Martin Company Limited, Baltimore and the Federal Aviation Agency's Experimental Center at Atlantic City
or
Pratt and Whitney Limited, Hartford.

9th October—by coach to:
Curtiss Wright Electronics and Propeller Divisions, Paterson, New Jersey and Reaction Motors, Denville, New Jersey.
or
Republic Aviation and Grumman Aircraft, Long Island.

11th October—by air to Cleveland.

12th October
N.A.S.A. Lewis Research Center.
Ford Motor Company Foundry and Engine Plant.

13th October
Thompson Ramo Wooldridge—Tapco Group.
By air to:
Cornell Aeronautical Laboratories, Buffalo
or
Bell Aircraft Corporation, Inc., Niagara Falls.

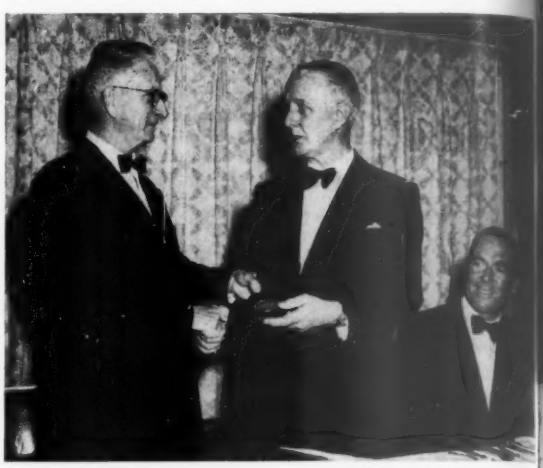
15th October
de Havilland Aircraft Canada Ltd. and Defence Research Medical Laboratories.

THE GRAND TOUR

8th October

For the visits made from New York on 8th and 9th October a choice had to be made each day. On the 8th one group was scheduled to fly to Hartford to visit Pratt and Whitney while the other group flew to Baltimore to the Martin Company and then on to the Federal Aviation Agency Experimental Center at Atlantic City. It was unfortunate that the weather was unco-operative that day, but in spite of some delays due either to having to take-off or land at airports other than those planned, both parties eventually reached their destinations.

The visitors to Pratt and Whitney spent the whole day there, visiting the laboratories, viewing engine test beds, the research and development facilities, and engines in every stage of construction. The tour of the factory was made in a procession of electric cars which saved the delegates much fatigue. The party were the guests of the Company for lunch, and the flights from New York to Hartford and back were made in an aeroplane of the United Aircraft Corporation.



During the presentation of the Elmer A. Sperry Award at the Conference Dinner, New York. Dr. T. P. Wright presenting the award for Mr. C. C. Walker to Dr. E. S. Moult. On the right, Sir Aubrey Burke.

Transport to Baltimore was provided by the Martin Company (Martin 202) and the F.A.A. (DC-3). Unfortunately weather delayed the departure for Baltimore so the visit was somewhat rushed, but on arrival at Martin Airport delegates found an impressive array of the missiles manufactured by the Company's Baltimore, Denver and Orlando Divisions—the first joint display to be so assembled. The missiles on display were: *Titan*, the Air Force two-stage intercontinental ballistic missile; *Mace*, the Air Force surface-to-surface tactile missile which is built at Baltimore; *Bullpup*, the Navy tactical air-to-surface missile; and *Lacrosse*, the Army surface-to-surface field artillery missile, with its mobile launcher.

A quick tour—by bus—of the large Martin domain at Baltimore showed that there was obviously much that delegates would like to have had time to see but after being entertained to lunch by the Martin Company in the Executive Dining Room the party, well behind schedule, flew on to the F.A.A. Experimental Center at Atlantic City. Here they were told, and shown by means of slides and film, something of the interesting work being done. Unfortunately they were by now so far behind schedule that they could only have a tantalising glimpse of much new equipment which was still in process of being assembled.

The flight back to New York was made in the Martin and F.A.A. aircraft and, as the weather contributed to a further delay in landing at La Guardia, delegates were thankful that there was no formal function that evening.

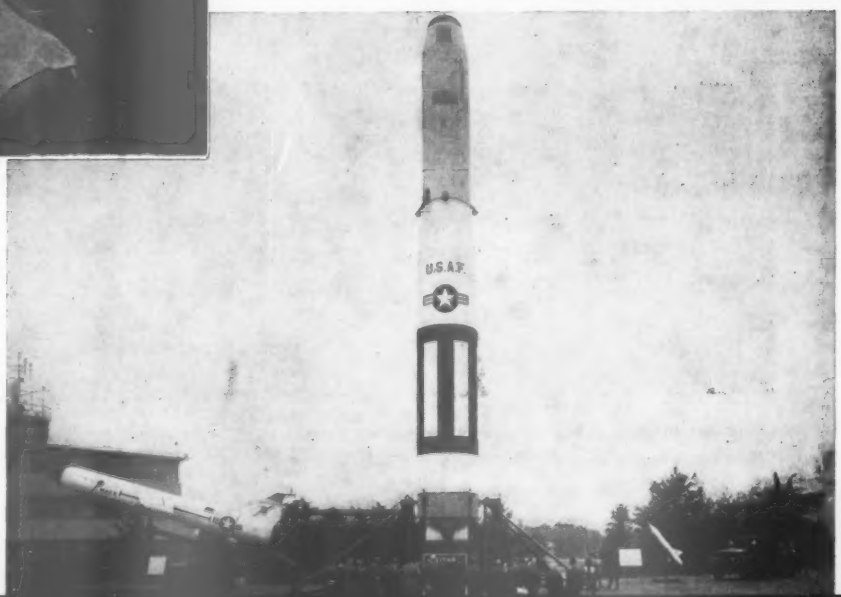
9th October

On 9th October the party again divided into two groups, one to visit Curtiss-Wright and Reaction Motors, both in New Jersey, and the other to make the trip to Long Island to visit Republic Aviation and Grumman Aircraft. Travel for both groups this time was by coach.

Those who visited the Curtiss-Wright Electronics factory had an interesting morning seeing some of the Simulators being built for Boeing 707 operators in various parts of the world, as well as a Simulator for one of the new Air Force combat aeroplanes. On the way to Sun Dance Lodge for lunch as the guests of Curtiss-Wright, a brief stop was made for a demonstration of the Curtiss-Wright Aircar, which was much enjoyed.

After lunch the party continued by coach to Reaction Motors Division of Thiokol Chemical Corporation, manufacturers of the engines used in the X-15. A quick tour of

Informal discussions at Republic Aviation, *above*; and *right top, and centre* at Pratt and Whitney.



Interest in the Bullpup, *above*, at Martin's Baltimore Airport, and *right*, a field lecture on Titan (*centre*). Mace is on the left.

the Research Laboratories at Denville was made and they were then driven to the Company's Test Area at Lake Denmark, seven miles away, and given some interesting demonstrations—at a safe distance— before visiting one of the rocket test stands.

The other group also had a full and interesting day, beginning at Republic Aviation with a tour of the assembly line for the F-105 fighter bomber and a most impressive model of Republic's expansion plans for the future. Everyone also spent some time having flaps, controls and air-brakes on the F-105 opened and closed for them. From Republic the party went to the Beau Sejour for lunch as guests of Grumman Aircraft Corporation and from there to the Grumman plant at Bethpage. There the delegates were told something of the Corporation's history, and given demonstrations of chemical milling and of skin milling, the latter automatically controlled by an I.B.M. digital computer. They also saw a static test on the support structure for the Martin-Baker ejection seat in the F9F-8B and were given a demonstration of the Grumman motion simulator. Finally they were shown round a completed Gulfstream before departing by coach for New York.

While the delegates were thus occupied the ladies were continuing their programme of sightseeing with a trip to West Point Military Academy on 8th October and to the Cloisters, New York, on the 9th October.

Delegates and their ladies were entertained to a Dinner-Dance at the St. Moritz-on-the-Park Hotel on 9th October as guests of a group of firms in the New York area—a most enjoyable occasion, even though it meant saying good-bye to many kind friends, for this was the finale of the Conference in New York.

Each lady at the dinner received a replica of the Institute's badge, in the form of a handsome silver brooch.

After a week of such intensive activities it was a relief to all the British delegates to find that they had Saturday and half of Sunday free (10th and 11th October) before setting out from New York on the journey north to Cleveland for the second half of their programme. For some this free time meant shopping and a little sightseeing, for others an opportunity to see something of the nearby countryside and to enjoy the warm hospitality of American friends in their homes.

11th-12th October

On Sunday 11th October delegates had the pleasure of flying in one of American Airlines Lockheed Electras from New York to Cleveland—an occasion to be remembered (and no doubt by the flight and cabin crews also, who probably did not expect the British to be quite so uninhibited). Dr. Hilton's ukelele as accompaniment for "rock'n' roll" high over America was "quite something"!

Cleveland provided a surprise—autumnal temperatures and chill winds in great contrast to the 90 per cent humidity and temperatures well in the 80s which had prevailed in New York. Representatives of the National Aeronautics and Space Administration were waiting to take delegates to the Airport Hotel—another interesting experience as few expected it, on the edge of a busy airport, to be so quiet.

That evening a reception and dinner were given by N.A.S.A., at the Lewis Research Center, which was indeed a pleasant occasion—where old acquaintances were renewed and friendships begun in the happy, friendly and informal atmosphere which prevailed.

Delegates would all have liked longer at N.A.S.A. the following morning. They were told about the Plum Brook Reactor Research facility but were unable to visit it as it was too far and time was too short. What fascinated everyone was the 6-degrees of freedom rig to simulate the control system of the Mercury capsule; this rig is to be used to train pilots to use the system of air jets as controls, as distinct from the usual aerodynamic type of control and the type of response associated with it. In addition the Supersonic and Altitude tunnels, the work being done in the materials building (where delegates had to shuffle round in bootees as a precaution against radioactive material), and finally the Electric Propulsion Department, where delegates saw the ion engine, the plasma jet and a model of a project to reach Mars, were intensely interesting and the morning was over all too quickly. However, the schedule had to be kept and, after luncheon as guests of N.A.S.A., there was a tour of the Ford Motor Company Foundry and Engine Plant—very much down to earth after the Space projects of the morning.

Meanwhile luggage had been removed from the Hopkins Hotel at the airport to the Pick-Carter in the city and that evening delegates were the guests of Thompson Ramo Wooldridge, Inc., at a reception and dinner held at the Thompson Museum. Here the delegates had a fascinating time inspecting old cars—an 1895 French Voiturette, 1908 Cadillac, a 1923 Model "T" Ford and dozens of other American types of the early 1900s—all in superb condition. The Aviation Section included a 1910 Curtiss Pusher and a DH-4. Another great attraction at the Museum was the

Dinner at the N.A.S.A. Lewis Research Center, Cleveland. In the centre foreground, Dr. Edward R. Sharp, Director of the Center with, on his left, Mr. Littlewood and right, Mr. Masefield, Sir Roy Fedden and Dr. Ballantyne.

At the rocket test site at Bell Aircraft, Niagara Falls.

replica of a main street—"Main Street, Thompsonville—1898"—and a Nickelodeon which some of the younger delegates heard for the first time and which played old tunes much to everyone's pleasure.

13th-14th October

Next morning an early start was made for a tour of the Tapco Group Plant of Thompson Ramo Wooldridge. Here delegates saw a display of the Group's products which included components for engines, jets, missiles and electronics systems; they then toured the huge plant seeing various forms of heat treatment, welding and forging and turbine and compressor blades in all stages of manufacture.

By 11.30 a.m. delegates had divided into their respective groups—some going to Niagara Falls to visit Bell Aircraft Corporation and others to Buffalo to the Cornell Aeronautical Laboratories—but all were to depart from Lost Nations Airport. (Alas, no one seemed to know the reason for that name.)

The group going to Bell Aircraft were flown to Niagara Falls by DC-3s of Thompson Ramo Wooldridge and those going to Buffalo were flown by courtesy of the Ford Motor Company and United States Steel Corporation, also in DC-3s. Lunch was served on board but once more unfortunately the weather prevented anything but brief glimpses of the countryside.

The Group which went to Bell Aircraft had a most interesting time. They were given short talks on various aspects of the Company's current work and then had the opportunity of examining, among other things, the blind landing control equipment being developed at Bell and a mock up of the D-188A fighter. Afterwards the party was taken to see, from a suitable distance, the test firing of a rocket engine.

A choice had had to be made at Cornell between a general tour of the laboratories and one specialising in hypersonics and both parties saw much of interest. The General Tour included brief glimpses of two of the tunnels, the Perceptron Programme—a most bewildering electronic system which may eventually be capable of a number of incredible things—a Terrain Simulator and work on radar detection of ballistic missiles, as well as some of the work on vehicle dynamics now being done at the laboratory. The other group spent some time with the new wave superheater developed for extreme conditions of hypersonic flight and, as always, everyone longed for more time.

All too soon the schedule had them back in coaches and on their way out of the United States and across the border to Canada—to rejoin the delegates who had been at Bell, and the ladies who had come on from New York, at the Sheraton Brock Hotel at Niagara Falls.

When the delegates left New York for Cleveland on the Sunday the ladies were taken by coach to Wilton, Connecticut, to spend the rest of that day and that night as guests of Mrs. Elmer A. Sperry. They returned to New York on the 12th October to attend a theatre—"Flower Drum Song"—which they all greatly enjoyed. The following morning they flew from Idlewild Airport to Buffalo and then drove to Niagara Falls, crossing the border into Canada.

That evening delegates and their wives were guests of Bell Aircraft and Cornell at a delightful reception and dinner held in the Rainbow Room of the Sheraton Brock Hotel, with magnificent views of both the American and Canadian Falls. When these were illuminated just as dinner began there was a rush to the windows but to the disappointment of many the illuminations were turned off about 10.30 p.m., just as a number of the delegates set off for a closer view after dinner.

The next morning was "open" and provided a welcome change from the early departures of many of the tours. Also, it gave everyone a chance to explore the Falls, from both sides of the border, although the weather was not helpful for colour photography.

After lunch coaches left for Toronto, where the Canadian Aeronautical Institute took over and proved equally hospitable, beginning with a reception at the Park Plaza Hotel.

15th October

In the morning delegates visited de Havilland Aircraft of Canada at Downsview where after a general briefing on the history of the company and the development of the Company's aeroplanes, the Chipmunk, Beaver, Otter and the new Caribou, these types were shown in a static display outside. An impressive flying demonstration of the Caribou was then given and delegates also watched a demonstration of the experimental STOL work being done on an Otter.

After a quick tour of the works and an excellent lunch as guests of de Havilland the party went on to the Defence Research Medical Laboratories on the other side of the aerodrome. Here delegates received a brief outline of the work being done, followed by short talks on Human Factors and Vestibular Physiology. Visits were then made to the Decompression Chamber and then, while some went to the Institute of Aviation Medicine to see the Human Centrifuge, others had a fascinating discussion on Environmental Physiology and watched some experiments.

That evening delegates were the guests of the C.A.I. at a reception and dinner—the last formal function of the Conference. Dr. D. C. MacPhail, President of the Canadian Aeronautical Institute presided at this important event—the first gathering of the three Societies in Canada. Although not a great many of the members of the C.A.I. were able to attend there were a number of old friends to greet, such as Dr. J. J. Green; also, Dr. Sharp had come from Cleveland and Paul Johnston and Bob Dexter had come from New York. Dr. MacPhail read a cable he had sent to His Royal Highness, the Prince Philip, Patron of the C.A.I. and the cable he had received from His Royal Highness sending his greetings and good wishes.

Dr. MacPhail welcomed the guests and thanked both the Society and the Institute for the help they had given in the formative years of the C.A.I.

The other two Presidents rose nobly to the occasion. They had stayed with delegates throughout the Conference,

The final Conference Dinner with the C.A.I. as hosts, at the Part Plaza, Toronto.

attended the Technical Sessions, gone on all the plant visits, spoken at all the formal functions, and thanked the hosts at all tour luncheons—always wittily, sincerely and with the right words at the right time.

On this occasion Mr. Masefield, after expressing pleasure at the Canadian Institute's participation in the Anglo-American Conference, again thanked the Institute of the Aeronautical Sciences for the warmth of their welcome and their great hospitality in New York and on the tours of the plants and laboratories, the smoothness of all their arrangements for delegates' comfort throughout the tours and the delightful hospitality given to the ladies by the American ladies.

16th October

On this last day of the Conference some of the delegates attended the closing session of the three-day Decennial Symposium of the University of Toronto, Institute of Aerophysics. The rest of the delegates followed later and all were guests of the University for luncheon.

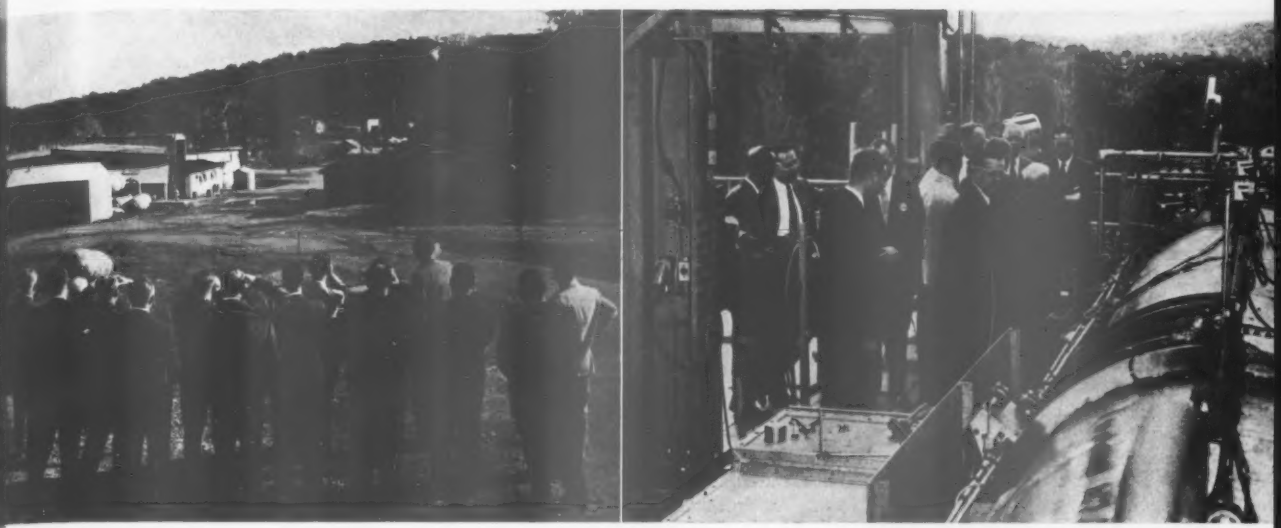
After luncheon there was a Panel Discussion on "Canada's Technical Role in the Space Age" under the Chairmanship of Dr. G. S. Field. Members of the Panel, each of whom gave brief papers which were followed by questions, were: Dr. J. C. Evvard, N.A.S.A.; Dr. D. C. Rose, N.R.C.; Dr. H. S. Ribner, U.T.I.A.; Dr. P. A. Lapp, de Havilland Aircraft; and Dr. J. J. Green, C.A.R.D.E.

Following the Panel Discussion, Conference delegates were privileged to be present at the official opening of the new Laboratories of the Institute of Aerophysics, University of Toronto. They were formally opened by Dr. A. H. Zimmerman, Chairman of the Defence Research Board, to the unusual accompaniment of an impressive volley of shock tube firings. A fitting finale for the Seventh Anglo-American Aeronautical Conference.

The Society now looks forward to the Eighth Conference in 1961.

To the President of the Institute, Mr. Littlewood, to Paul Johnston, Bob Dexter, Marjorie Rode, "Shrade," Joe Maitan, John Ball, Tom Meskel, John Bidwell, Joe Ryan and Tony Harris and all the staff of the Institute who worked so hard; to Dr. D. C. MacPhail, President of the C.A.I., Mr. H. C. Luttman, Secretary, and Mrs. Ross; to Dr. and Mrs. Sharp and the Staff at the Lewis Research Center; to Dr. Ira G. Ross, President of Cornell Aeronautical Laboratories, Dr. T. P. Wright of Cornell, and everyone there; and to everyone at Martin's, the F.A.A., Curtiss-Wright Electronics Division, Reaction Motors, Grumman, Republic, Thompson Ramo Wooldridge, Ford's, United Aircraft Corporation and Bell Aircraft—to everyone who gave so much time and help to make the Seventh Anglo-American Aeronautical Conference a memorable one, the British delegates say a sincere "Thank you."

At the C.A.I. Dinner in Toronto. *Left to right*, Mr. R. R. Dexter, Secretary, I.A.S.; Mr. William Littlewood, President, I.A.S.; Dr. A. M. Ballantyne, Secretary, R.Ae.S.; Dr. D. C. MacPhail, President, C.A.I.; Mr. H. C. Luttman, Secretary, C.A.I.; Mr. Peter G. Masefield, President, R.Ae.S.; and Mr. S. Paul Johnston, Director, I.A.S

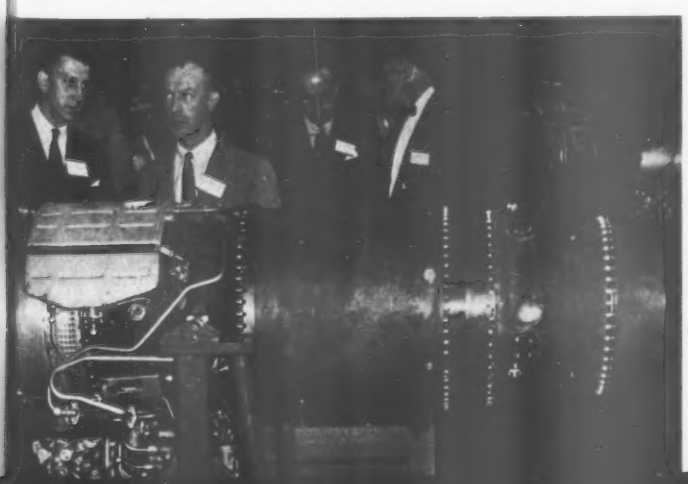


During the Reaction Motors tour: *left*, waiting for a rocket test (the puff of smoke at the top of the picture is the focal point) and *right*, up at the rocket test stand later.

Mr. Masefield, Professor Collar and Mr. Keith Lucas interested in plants growing under very low pressure conditions at Republic Aviation.

Delegates disembarking at the Martin Airport, Baltimore.

Below: Delegates during the Pratt and Whitney tour.



At de Havilland Aircraft of Canada, Downsview, Toronto, with the nose of the Caribou on the right.

THE LIBRARY

Reviews

METAL FATIGUE. *G. Sines and J. L. Waisman (Editors). McGraw-Hill, London, 1959. 415 pp. Illustrated. 97s.*

This book is based on a number of papers first presented in 1953 and revised to include material up till, perhaps, mid-1958. In all, there are some sixteen authors, each well-known in his field. The whole is aimed at the practising engineer rather than the specialist and is in the main successful. It is a disappointment that more has not been said about the scourge of fretting in structures, crank propagation and loading actions, including the effects of heat; but such a criticism is not justifiable when the time of writing is considered in relation to the rapid developments in these particular directions. The specialist may well take issue with certain details, but even the specialist will benefit from the wide range of subjects treated and will certainly find the extensive bibliography most helpful.

The Introduction discusses the problem of fatigue and the factors affecting fatigue strength, a rapid survey as it were. Concepts of fatigue damage, such as dislocations, slip and the statistical nature of fatigue damage are discussed by Dolan. Peterson considers fatigue cracks and fracture surfaces. Testing machines, test specimens, test procedure and techniques and the interpretation of results are dealt with by Hartmann and Howell; both material specimens and complete components are included. McLintock contributes on the statistical planning and interpretation of fatigue tests, proceeding easily from the use of tables of random numbers to Gaussian and extreme value theory. The behaviour of metals under complex static and alternating stresses is outlined by Sines, showing the applicability of various stress criteria such as principal stress, maximum shear stress and octahedral shear stress. The effects of residual stress, whether tension or compression, are considered by Rosenthal, while Fuchs deals more particularly with the consequences of surface stressing techniques, such as shot peening, quenching, nitriding, and so on. Grover notes that, at high temperature, fatigue is vastly complicated by creep and metallurgical changes in the material, and emphasises that much remains to be done. McDougal illustrates the operational loads on an aircraft using the measurements of turbulence made by N.A.C.A. (now N.A.S.A.); the discrete gust presentation is adopted rather than that of power spectra. A chapter on the estimation of cumulative damage is compiled by Miner, who demonstrates the convenience and the limitations of the simple cumulative rule, $\Sigma(n/N)=1$. A second paper by Peterson is about notch sensitivity, and hence of theoretical and effective stress concentration factors; attention is drawn to the need for more basic data on, for example, steep stress gradients. Grover assembles some typical data on the fatigue life of structures covering riveted joints, welded joints, bolted joints, and on the behaviour of composite structures. This is supported by a paper by Spaulding on how the designer of aircraft wing structures goes about his task. Boswell and Wagner cover fatigue in rotary wing aircraft, outlining the cyclic loadings that occur, fatigue testing under those loadings and closing with examples of typical failures. The final chapter by Christensen treats of the detection of fatigue damage, discussing crack growth, the residual strength of cracked structures and the various techniques of crack detection.—R. J. ATKINSON.

JANE'S ALL THE WORLD'S AIRCRAFT, 1959-60. *Fiftieth Year of Issue. Compiled and Edited by Leonard Bridgman. Sampson Low, Marston, London, 1959. £5 5s. 0d.*

Year by year reviewers of "Jane's" run out of superlatives and many an editorial head has been hastened towards baldness with this annual task. Not that it is a chore—far from it—Jane's has a mesmeric attraction. This year's editorial quoted that distinguished authority on aeronautics, Captain J. Laurence Pritchard, writing nine years ago that ". . . . Jane's is one of the best reference books published." This reviewer supports that comment with one addition: Jane's Jubilee edition is obviously one of the best ever published.

The preface, as usual, is an admirable overture giving the reader a taste of the most interesting things to be found in the text. This also contains an interesting word picture of Fred T. Jane himself and is followed by biographical notes on the three editors, Jane, C. G. Grey and Leonard Bridgman who is now retiring from this exacting task after 19 years in the editorial chair and before that 21 in association with C.G. A brief chronology of aeronautical events of 1909 precedes the elaborate index.

The body of the book is substantially the same as hitherto. The illustrations and particularly the excellent drawings of L. E. Bradford are as good as ever. The aeroplane section is bigger than ever. The last vestiges of the historical side of the Jane's series have now been dropped altogether with the elimination of the military and civil sections. Their place is taken by "Guided Missiles and Test Vehicles."

This year, to mark the occasion of the Golden Jubilee of Jane's, some of the pages of the first edition, published in 1909, are reproduced at the end of the book. It is an interesting finale particularly since both issues and indeed the whole series were printed by Netherwood Dalton and Co. and published by Sampson Low, Marston and Co. Ltd. Jane's is the greatest credit to editors, printers and publishers and a fine example of the art of printing.—A.S.C.L.

MEDICAL ASPECTS OF FLIGHT SAFETY (The Unexplained Aircraft Accident). *E. Evvard, P. Bergeret and P. M. van W. Palthe (Editors). AGARDograph 30. Pergamon Press. London, 1959. 317 pp. Illustrated. 80s.*

Of the thirty papers in this book (selected from two symposia of the AGARD Aeromedical Panel), seven are in French. The brief English abstracts are of little use, but even those readers who, like the present reviewer, have not progressed beyond the "Plume de ma tante" level will find little difficulty. The favourite saying of those who make a cult of French that some French words cannot be translated into English is only true in the trivial sense that several English words may be needed to convey the exact shade of meaning—or that Frenchmen entertain

ideas of which an Englishman would be incapable; such ideas do not appear in technical writing. Nevertheless, if a job is worth doing at all, it is worth doing well and, had the book been worth it, two editions, one in each language, would not have been beyond the resources of NATO. The symposia were held in 1956 and 1957, so there was plenty of time.

This is typical of the general impression conveyed. The subject is presumably important and serious, and some of the authors have treated it so, although it is difficult to find anything both new and valuable. Nobody can make original discoveries or even have worthwhile "bright ideas" to order; but the place for sound expositions is something having the coherence and consistence of a good textbook, not a hurried collection ("selection" was surely a euphemism) of heterogeneous talks prepared for an international beanfeast.—W. E. HICK.

AIR ACES OF THE 1914-1918 WAR. *Bruce Robertson (Editor). Harleyford Publications. 45s. Contributors: J. M. Bruce (for British air forces); Capt. E. F. Heyn, U.S.A.F. (for American); D. A. S. McKay, D.F.M. (for French and Italian); Major V. Houart (for Belgian); H. J. Nowarra (for German); Miss J. Alexander (for Russian); and W. M. Lamberton (for Austro-Hungarian). Producer: D. A. Russell.*

No one who is even superficially interested in the air fighting of the First World War should miss reading this book. It is (so far as I know) the only volume to present the story from the individual angles of all the belligerent air forces (excepting the Turkish, which was small and may not have produced a single "ace"). Thus it is here possible to study, contrast and compare methods, machines and men of the war that evolved aerial fighting with a directness and ease hitherto denied the reader because of the language barrier and the wide dispersal of original material.

A standard format is used for each self-contained section. First is given an historical sketch of the national air force and of those concerned with its creation and control and to a lesser degree of those who conceived, designed and produced the aeroplanes used. Although necessarily compressed, these brief introductory histories are good and the reader has the opportunity to analyse the national characteristics of the eight powers in relation to the early period of military flying. Then follow brief biographies of some of the more prominent of each nation's fighting airmen; here the balance is not held so evenly because it has evidently been found impossibe to maintain a standard whereat to include (or exclude) those biographed; this unbalance becomes apparent when studying the third and last part of each section, wherein are listed the air aces of each belligerent (plus in the British, German and American sections, additional lists of V.C., Pour le Mérite, and Congressional Medal of Honor awardees).

In some countries the term "ace" (German *"kanone"*) was applied to airmen with not fewer than 10 victories. In some other countries five was the lowest common denominator. This book takes the lower basis. This favours the Americans, who came into that war very late and who are shown to have had but nine U.S. Air Service airmen who scored 10 and more, plus another American who served only with the French. If the 138 biographies were proportionately applied to the 452 airmen listed as having scored 10 or more victories there ought to be one biography to each 3·27 airmen; thus awarded the British would receive 57 biographies, the Germans 51, the French 16, the Austro-Hungarians 5, U.S.A. and Italy 3 each, Russia and Belgium 1 each. Instead, one finds the Americans awarded 29 biographies, the British 23, the Germans 22, the French 21, the Russians 19, the Italians 13, the Austro-Hungarians 6 and the Belgians 5.

One suspects that the commercial aspect of publication—especially in relation to the American market—here crept in. But none could complain that the biographies, although lop-sided, are uninteresting. Indeed, they are fascinating as studies of individual personalities and of methods of air fighting. We see how some men chose the single-handed method, others the formation leadership form (although to some extent this was conditioned by the period, because formation tactics altered between 1916 and 1918); how some specialised in combat with enemy scout fighters, while others selected the (perhaps easier) two-seaters; yet others concentrated on observation balloons (whose destruction counted equally with aeroplanes) because they found they could hit them more easily than they could hit moving aeroplanes and willingly (and sometimes wilfully) dared the heavy and often deadly A.A. fire to win their scores. (In the First World War aeroplanes destroyed on the ground did not count as victories, as they did with the Americans in the Second World War.)

The champions of balloon-busting were Coiffard (France) 28, Coppens (Belgium) 26, Ehrlich (France) 18, Gontermann (Germany) 17. Beauchamp-Proctor (South Africa) 16, Luke (America) 15, Barker (Canada) 9. It was a dangerous game, but it was not air fighting. Of those mentioned only Barker, Gontermann and Beauchamp-Proctor exceeded their balloon scores in true air fighting.

It is noteworthy that 81 German airmen received the Pour le Mérite (19 more were awarded, but the intended recipients did not receive their decorations), whereas only 19 air V.C.'s were awarded, including posthumous awards. Perhaps also it is characteristic that the V.C. is a plain bronze medal worn on the chest irrespective of rank and the Pour le Mérite is a gold and enamel neck decoration for which only officers are eligible.

Lavishly illustrated with photographs, indexed and commendably free from compositors' errors as this book is, I found it impossible to accept the victory score lists as completely reliable. The British list omits some names, gives some inaccurate scores, contains lapses in initials and in decorations after names. But it is a most difficult and laborious task, perhaps almost impossible, to compile a full and accurate list of so many men and be completely certain that every detail is correct. The lists given should be regarded as a general guide, not accepted as infallible. From a close study of them one finds further evidence of that genetic quality in the British people which produces a better average fighting man who, in the mass, has enabled them for generation after generation to meet their great emergencies and triumph over them. Secondly, one observes how, despite the improvement in their aircraft and armament in the second and longer 1939-1945 air war, no British fighter pilot then reached the high scores of the first 16 or so of British air fighters of 1914-1918. Perhaps those first fighter pilots were helped by freedom from ground control, which fortunately or otherwise (dependent on the point of view) was non-existent in the 1914-1918 air war. Swashbuckling airborne independence gave the fighting airmen of that war the right to evolve their own rules of aerial combat. This surrounded them with a special Arthurian jousting

glamour that continues to attract a deepening interest in their storied deeds among the succeeding generations by whom this book will be teasured.

Finally, one pays tribute to the contributors, editor and producer for a valuable production and records with regret the recent death of contributor D. A. S. McKay, of Pontefract who, in the second war, himself scored at least eight victories.—NORMAN MACMILLAN.

FUNDAMENTALS OF RADIO TELEMETRY. *Marvin Tepper. Chapman and Hall, 1959. 115 pp. Illustrated. 24s.*

The author states that his aim is to present a general overall picture of his subject without too much detail. He does not say that he writes for any particular type of reader but a foreword suggests that a basic knowledge of electronics is assumed. For much of the way such background is well-nigh essential since the author does not hesitate to refer to such items as the Yagi aerial and the solar cell without explanation. At times, however, he seems desirous of reaching a wider audience, as where he explains (?) that bandpass filters are tuned circuits that pass only a specific band of frequencies. He makes generous use of "pictorial" illustrations and block diagrams, both well done. The chief subjects surveyed in Chapters 1-7 are sensing elements; multiplexing and coding; receivers and recorders. The eighth chapter is a brief account of telemetering equipment in Explorers I, III, IV, Vanguard I and Pioneer I. There is a five-page bibliography; all of the references are of U.S. origin with nothing later than 1955 and very little before 1951.

Although radio-telemetry has been used for more than 30 years (longer than the author thinks) and has been the subject of many papers there is a surprising scarcity of textbooks. A tutorial book such as this is therefore likely to be of use to some readers at least. The fundamental problem of compressing and sifting material to provide an overall survey which, while remaining clear and coherent, occupies less than 100 pages is formidable and the author would have done better to have been less ambitious in compression. He is not to be blamed for not covering all the prodigious variety of sensing elements and techniques since that is not his aim but, if he is addressing readers with an electronic background, one might reasonably expect him to omit explanations of things they should already know (*e.g.* thermistors) in favour of such topics as PPM and Microlock which are just as important as those he includes or at least provide a more selective and less parochial bibliography with appropriate text-pointers to this on subjects requiring study elsewhere. The text as it stands will help any electronic engineer requiring an introduction to the field so long as he realises that there is a good deal more to be said on both fundamentals and details; other engineers may usefully read it, skipping the electronics as desired, for an insight into some of the hardware that has been used.—L. W. MEYER.

DIE ALTEN ADLER. *W. Hackenberger. Lehmanns, Munich. 185 pp. Illustrated. D.M.16.80. (In German.)*

The book is dedicated to the memory of Otto Lilienthal (1848-96), Germany's first aviator, and to all who gave their lives to the cause of aviation. Dipl.-Ing. R. Thelen, holder of German Pilot Licence No. 9, and Major-General Kammhuber of the German Air Force, the former prominent in German aviation in the past and the latter today, have written the prefaces, praising the "Alten Adler," the "Old Eagles" and their undaunted conquest of the air since Orville Wright flew first over Berlin, fifty years ago.

The purpose the book is expected to serve is: to rouse such enthusiasm anew, by paying tribute to the "old eagles." Under the motto: "Yet—see a pair of wings—unfoldeth straight! Thither, I must, I must—grudge not my flight!" (Euphorion in Goethe's Faust II/3) the idealism in the early days of human flight is stressed by the author in the introduction, when men of different background sacrificed fortunes and lives for the purpose of materialising this ancient concept of men. These were the pioneers of the early days of aviation, who had been either flying or building aeroplanes or were somehow prominent in German aviation before the First World War. About three hundred, of the once eight hundred, who survived, are honorary members of the German Aero Club.

The author, in his effort to illustrate their stride as truly as possible, is supported by the German Aero Club and by old pilots who contribute with narratives, confined to personal memory and experience.

Throughout the book almost 600 names are mentioned and these are also listed in index form. Although most of these names perhaps never gained notoriety at the time and are of no significance in the history of aviation, they produce, as a whole, an impressive background against the modesty of these stories which are told in good style, and which contribute to interesting reading in spite of a lack of excitement often met with in modern aviation stories—or may be—it is the simplicity of statements such as: "the pilot had to shape the propeller himself" which makes the book particularly impressive.

Thus we are presented with a striking illustration of the ideology of the early days of aviation in Germany. Whether the German youth of today will have the receptiveness for the values they are offered through this book is beyond the reviewer's judgment. The book is well prepared and the old-time photographs are an excellent example of careful reproduction.—E. S. KRAUSS.

Additions to the Library

Advanced Aero Engine Testing. Edited by A. W. Morley and J. Fabri. Pergamon, London. 1959. 298 pp. Illustrated. 63s. *To be reviewed.*

Aircraft and Missiles. D. M. Desoutter. Faber and Faber, London, 1959. 213 pp. Illustrated. 36s. *To be reviewed.*

Analysis and Design of Aircraft Structures. Volume I. Analysis for Stress and Strain. Second Edition. E. F. Bruhn and A. F. Schmitt. Tri-State Offset Co. (G. E. Haagens, 26 Pondfield Road, West, Bronxville, New York). 1958. 452 pp. 10.50 dollars. The first edition of this working textbook appeared in 1943 and this new, photo-reproduced edition is to be published in two parts, Volume I, now available, and Volume II—Strength Analysis and Design—in preparation. Professor Bruhn is Professor of Aeronautical Engineering at

Purdue University and Dr. Schmitt is with Convair Astronautics. In the next printing of Volume I, due for mid-1960, a new section is to be added on thermal stresses.

Dictionary of Aeronautical Engineering. J. L. Nayler. Newnes, London, 1959. 318 pp. Diagrams. 30s. *To be reviewed.*

Die alten Adler. Willi Hackenberger. Lehmanns, Munich, 1959. 185 pp. Illustrated. 16.80 DM. *Reviewed in this issue.*

Explosions, Detonations, Flammability and Ignition. Agardograph 31. B. P. Mullins and S. S. Penner. Pergamon, London. 1959. 287 pp. Illustrated. 70s. *To be reviewed.*

Fuels and Lubricants. M. Popovich and C. Hering. Chapman and Hall, London, 1959. 312 pp. Illustrated. 68s. *To be reviewed.*

Fusées et Engins Guidés. Recueil des rapports du ler congrès international des Fusées et Engins Guidés. (1956-7.) Association pour l'Encouragement à la Recherche Aeronautique. 1959. 300 pp. Illustrated. (In French.) Under eight main headings—Propulsion, Ballistics, Aerodynamics, Electronics, General, Materials, Space Law and Space Medicine—the volume contains 60 of the papers presented at the first international conference on rockets and guided missiles, held in Paris at the end of 1956, and organised by the Association pour l'Encouragement à la Recherche Aeronautique. Nearly all the papers have been printed in French, although the authors are drawn from many other European countries, from the United States and from the U.S.S.R.

Handbook of Automation, Computation and Control. Volume II. Computers and Data Processing. Edited by E. M. Grabbe and others. Wiley, New York. (Chapman and Hall, London). 1959. 1,030 pp. (Sectional.) Illustrated. £7. *To be reviewed.*

Internal Stresses and Fatigue in Metals. G. M. Rassweiler and W. L. Grube (*Editors.*) van Nostrand, London, 1959. 451 pp. Illustrated. 72s. *To be reviewed.*

Introduction to the Mechanics of the Solar System. Rudolf Kurth. Pergamon, London, 1959. 177 pp. 42s. A text for an undergraduate course on celestial mechanics. The ground covered includes kinematics of the planetary motions; the two-body problem; perturbations; the motions of extended bodies. Poisson's powerful method of perturbations has been rediscovered and applied; in particular an interpretation of the perturbation of Mercury's perihelion is given within the frame of Newton's mechanics.

Jet Propulsion Engines. (High Speed Aerodynamics and Jet Propulsion, Volume XII.) Edited by O. E. Lancaster. Oxford University Press, London. 1959. 799 pp. Illustrated. £7. *To be reviewed.*

Konstruktive, theoretische und experimentelle Beiträge zu dem Problem der Flüssigkeitsrakete. Wernher von Braun. Deutscher Gesellschaft für Raketentechnik und Raumfahrt, 1959. 47 pp. 9.60 DM. This is a reprint of von Braun's 1934 dissertation for his Ph.D.

Laplace Transforms for Electronic Engineers. J. G. Holbrook. Pergamon, London. 1959. 259 pp. Diagrams. 50s. *To be reviewed.*

Le vol des avions. Jean Renaudie. Presses Universitaires de France, 1959. 127 pp. This is No. 827 in the excellent little series of paperbacks, "Que sais-je." Starting with the atmosphere it continues through aerodynamics, engines, flight, simulation and so on to space flight. While not likely to be used as a textbook it makes a most useful book to carry round in the pocket for an occasional French exercise in technical literature.

Mechanisms and Motion. K. Hunt. English Universities Press, London. 1959. 214 pp. Diagrams. 21s. *To be reviewed.*

Non-homogeneity in Elasticity and Plasticity. Edited by W. Olszak. Pergamon, London. 1959. 528 pp. Diagrams. £5. Contains 52 papers prepared for the Symposium held in Warsaw in September 1958 and organised by the International Union of Theoretical and Applied Mechanics in co-operation with the Polish Academy of Sciences. Most of the papers are written in English, although only one is of British origin; many are from iron curtain countries, which is only natural, considering the venue of the Symposium. The papers are grouped in six sections—Elasticity, Plasticity, Rheology, Dynamics and Wave Propagation, Statistical and Micro Non-Homogeneity, Varia.

Standard Specification for Construction of Airports. U.S. Federal Aviation Agency (Bureau of Facilities). 1959. U.S.G.P.O. (H.M.S.O.). 588 pp. 24s. 9d. The specification items contained in this book are for the construction of airports and airparks in the United States and its possessions. Items covered are clearing and grubbing, grading, drainage, paving, lighting, turfing, and incidental construction items.

Theory of Matrices, The. Volumes I and II. F. R. Gantmacher. Chelsea Publishing Company, New York. 1959. 373 and 276 pp. 12 dollars. *To be reviewed.*

Theory of Plates and Shells. Second Edition. S. Timoshenko and S. Woinowsky-Krieger. McGraw Hill, London, 1959. 580 pp. Diagrams. £5 16s. 6d. This revision of Timoshenko's well-known book takes account of new methods and new aspects of plate and shell theory and design contained in the wealth of literature published since 1940, when the book first appeared. An article has been added on the deflection of plates owing to the transverse shear, and a special chapter on bending of anisotropic plates has been included. The chapter on non-linear bending of plates is considerably enlarged. The three chapters on shell theory now include the use of Pucher's stress function and outline the design of cylindrical roof shells. An article on the theory of shallow spherical shells is added. There is a systematic review of special and approximate up-to-date methods used in the design of plate bending. The use of influence surfaces is illustrated by several examples.

Theory of Space Time and Gravitation, The. V. Fock (N. Kemmer, Translator). Pergamon, London. 1959. 411 pp. £5. Covers both special relativity and what is usually called general relativity. Its earlier chapters present standard theory at a level at which it can serve as a textbook for final year Honours students in Mathematical Physics as well as research students. The remaining parts of the book are on post-graduate level, but the subject matter is presented as a textbook rather than as a specialist monograph. The book should have a special appeal to theoretical physicists who are not primarily relativists for they will find in it a great number of concrete applications of general relativity presented in a systematic and clear form. There is a comprehensive bibliography.

Theory of Thin Shells. V. V. Novozhilov. Noordhoff, Groningen. 1959. 376 pp. Diagrams. 68s. *To be reviewed.*

Wooden Wonder, The. E. Bishop. Parrish, 1959. 168 pp. 16s. A general interest version of the genesis and development of the Mosquito. Profusely illustrated.

World Aviation Directory. Marion E. Grambow (Executive Editor). American Aviation Publications, 1959. 11 dollars. It would seem that the addition of a sub-title "including Missile/Space industries" (or perhaps it is the necessity to list N.A.S.A.) accounts for nearly 60 more pages in this "Fall/Winter" edition than appeared in the Spring/Summer. It will cost £3 18s. 9d. in this country, from Norall and Hart Ltd., 28 Bruton Street, London, W.1. (GROsvenor 8356). It is, of course, a "must."

I.A.S. Papers presented at National Midwestern Meeting

Paper No. (Whichita, 2nd-4th November 1959)

59-149 Present and near-future use of aircraft in agriculture. F. Weick.

59-148 Present and future air potentialities in fire fighting, resource management and protection. C. Ferris.

S.A.E. Papers presented at National Summer Meeting

Paper No. (Los Angeles, 1959)

103U The JT 12 Pratt and Whitney aircraft's 3,000 lb thrust turbojet engine. D. G. Phinney.

104T Elevated temperature testing of flight vehicle materials. A. V. Levy and E. C. Bernett.

108V The estimation and preservation of turbine powered transport structural fatigue life. J. P. Butler.

Reports

AERODYNAMICS

BOUNDARY LAYER *see also* FLUID DYNAMICS
THERMO-AERODYNAMICS
WINGS AND AEROFOILS
TESTING AND INSTRUMENTS
PROPELLERS
FLIGHT TESTING

Large-scale wind-tunnel tests of an airplane model with an unswept, aspect-ratio-10 wing, two propellers, and blowing flaps. R. N. Griffin et al. *N.A.S.A. Memo* 12-3-58*A. TIL* 6103. *Dec.* 1958.
An investigation was made to determine the lifting effectiveness and flow requirements of blowing boundary layer control applied to a propeller-driven aeroplane.—(1.1.6.1×1.3.4×29.9).

Heat transfer in the turbulent incompressible boundary layer. I—constant wall temperature. W. C. Reynolds et al. *N.A.S.A. Memo* 12-1-58*W. TIL* 6144. *Dec.* 1958.
Heat transfer rates, velocity profiles, and temperature profiles for the turbulent incompressible flow of air over a flat plate with a constant surface temperature have been measured at Reynolds numbers up to $3{\cdot}5\times10^6$.—(1.1.3.1×1.9.1×34.3).

Heat transfer in the turbulent incompressible boundary layer. IV—effect of location of transition and prediction of heat transfer in a known transition region. W. C. Reynolds et al. *N.A.S.A. Memo* 12-4-58*W. TIL* 6145. *Dec.* 1958.
The effect of location of transition on heat transfer to the turbulent incompressible boundary layer is analysed. If the extent of the transition region is known, the analysis also allows adequate prediction of heat transfer coefficients within the transition region. The analysis should also predict local shear coefficients in the transition region.—(1.1.3.1×1.9.1×34.3).

Experimental observation of vortices in wing-body junctions. A. Stanbrook. R. & M. 3114. 1959.—(1.1.4.4×1.6.1×1.10.2.2).

An approximate method of calculating the laminar boundary layer in two-dimensional incompressible flow. M. R. Head. R. & M. 3123. 1959.
The use of a doubly-infinite family of boundary layer velocity profiles enables the momentum and energy integral equations of the boundary layer to be satisfied exactly, together with the first compatibility condition at the surface. The principal characteristics of the velocity profiles used have been calculated, and are presented graphically in a series of charts which enable calculations to be carried out with a minimum of labour.—(1.1.1.1).

Approximate calculations of the laminar boundary layer with suction, with particular reference to the suction requirements for boundary layer stability on aerofoils of different thickness/chord ratios. M. R. Head. R. & M. 3124. 1959.—(1.1.1.1×1.1.5.1×1.10.1.1).

COMPRESSIBLE FLOW *see also* FLUID DYNAMICS
INTERNAL FLOW
LOADS
THERMO-AERODYNAMICS
WINGS AND AEROFOILS
AIRCRAFT OPERATION

The 'Newtonian' theory of hypersonic flow for any three-dimensional body. N. C. Freeman. C.P. 439. 1959.
The Newtonian theory of hypersonic flow ($M=\infty$, $\gamma\to1$), originated by Busemann (1933) and developed by the author, is extended to flow past any three-dimensional body shape. Mathematical complexity however limits the results obtained to those for slightly yawed axially symmetric bodies and in particular the cone is considered in some detail. Pressure distribution and shock shape are obtained to a first approximation in $(\gamma-1)/(\gamma+1)$, and to a second approximation in $\sin\delta$ where δ is the angle of attack.—(1.2.3.1×1.4).

One-dimensional treatment of weak disturbances of a shock-wave. A. Powell. C.P. 441. 1959.
A shockwave enters a region of fluid initially at rest; the shock-wave motion is disturbed by interaction with sound waves or temperature fluctuations. It is the resultant sound waves and temperature changes behind the shock which are discussed. The Appendix outlines a corrected version of an earlier treatment which considered an initially stationary shockwave. Numerical values of the interaction coefficients up to $M_1=5$ are given —(1.2.3.2).

Methods of calculating fundamental solutions of the wave equation, with tables. W. A. Mersman. N.A.S.A. T.N. D-86. Oct. 1959.
Methods of computing two specific, fundamental solutions of the wave equation are presented. These solutions are applicable to certain problems in the theory of wing-body interference in supersonic flow. One of the functions has been tabulated previously, and tables of the second function are presented.—(1.2.3×27.1).

Experiments with inclined blunt-nosed bodies at $M_0=2{\cdot}45$. I. M. Hall et al. *R. & M.* 3128. 1959.
The flows about flat-nosed and hemispherical bodies of revolution were studied at incidences up to 28°. Schlieren photographs were taken in the plane of symmetry and the vortex wake was studied by the vapour-screen technique. Surface-pressure measurements were made, and the results integrated to give the axial forces and the distributions of normal forces on the bodies.—(1.2.3×1.6.1).

Calculation of the thickness and radial force distribution for a ring wing having zero drag at supersonic speeds. R. M. Licher. Douglas Report SM-23579. May 1959.—(1.2.3.1×1.4×1.10.1.2).

CONTROLS *see also* BOUNDARY LAYER
STABILITY AND CONTROL
WINGS AND AEROFOILS
PROPELLERS

Computation of the increment of maximum lift due to flaps. A. Roshko. Douglas Report SM-23626. July 1959.—(1.3.4×1.3.7×1.10.1.1).

FLUID DYNAMICS *see also* COMPRESSIBLE FLOW
WINGS AND AEROFOILS
HELICOPTER AERODYNAMICS

Non-equilibrium theory of an ideal-dissociating gas through a conical nozzle. N. C. Freeman. C.P. 438. 1959.
The one-dimensional flow of an ideal dissociating gas in non-equilibrium flow through a conical nozzle is investigated using the simple rate equation of Freeman (1958). The effect of the rate Λ (the ratio of the time scale of the motion to that of dissociation) on the flow is investigated for one set of initial conditions.—(1.4×1.5.1.4×1.2.3.1).

Principle of the least potential of the flow. V. I. Skobelkin. R.A.E. Trans. 837. *Sept.* 1959.—(1.4.1×1.2.0.1).

Mixing of wakes in a turbulent shear flow. S. Eskinazi. N.A.S.A. T.N. D-83. Sept. 1959.
Measurements were taken in the wake of a two-dimensional cylinder placed in a fully developed turbulent viscous layer inside a two-dimensional channel. The experimental survey consisted mainly of distributions of temporal mean velocity and static pressure and turbulence measurements.—(1.4.2×1.1.3.1×34.1.1).

INTERNAL FLOW *see also* FLUID DYNAMICS
LOADS
TESTING AND INSTRUMENTS

Measurements of velocity fluctuations in the working section of the R.A.E. 4 ft.×3 ft. wind tunnel with flow disturbances in the second diffuser. J. A. Lawford. C.P. 455. 1959.
An attempt has been made to determine whether a large contraction ratio and wire gauze screens in the maximum section would prevent unsteadiness of flow in the return circuit from affecting the flow in the working section.—(1.5.1.3×1.5.1.4).

A three-dimensional flow expander as a device to increase the Mach number in a supersonic wind tunnel. R. J. Salmi. N.A.S.A. Memo 10-6-58E. TIL 6105. *Dec.* 1958.
The operating characteristics of a 5° conical flow expander were investigated in the Lewis 2 ft.×2 ft. Mach 3·88 wind tunnel to determine the feasibility of using this type of device to increase the Mach numbers in conventional supersonic wind tunnels.—(1.5.1.4×1.2.3).

An experimental study of rotating stall in a two-stage axial compressor. R. F. Meyer. N.R.C. Report LR-259. Aug. 1959.
The stalling behaviour of an Orenda CT-100, experimental, two-stage axial compressor was studied at the constant operating speed of 3000 r.p.m.—(1.5.2.1).

LOADS *see also* BOUNDARY LAYER
COMPRESSIBLE FLOW
WINGS AND AEROFOILS
TESTING AND INSTRUMENTS
INSTRUMENTS AND EQUIPMENT

Calculation of the load distribution over a wing with arbitrary camber and twist at sonic speed. K. M. Mangler. R. & M. 3102. 1959.
A method is developed for the calculation of the load distribution due to camber and twist over a thin wing at sonic speed or, more generally, a wing for which (A^2/M^2-1) is small, A being the aspect ratio of the wing and M the free-stream Mach number. The calculation is based in the usual assumptions of linearised potential flow. Some simple examples show the effect of twist and camber on the load distribution and on the suction force along the leading edge of a delta wing. A family of linearly twisted wings with straight-edged plan forms is considered in some detail.—(1.6.1×1.10.1.2×1.2.2.1).

Analysis of acceleration, airspeed, and gust-velocity data from a four-engine turboprop transport operating over the Eastern United States. M. R. Copp and M. W. Fetner. N.A.S.A. T.N. D-36. Sept. 1959.
Time-history records of air speed, altitude, and acceleration were obtained with an N.A.S.A. V.G.H. recorder installed in a four-engined turbo-prop transport. The results obtained were then compared with the results previously obtained from two long-haul operations utilising transports equipped with four piston-type engines and flown over essentially similar routes.—(1.6.3×1.6.2×1.5×24).

Dynamic analysis of a simple reentry maneuver for a lifting satellite. F. C. Grant. N.A.S.A. T.N. D-47. Sept. 1959.
Calculated angles, times, distances, and accelerations associated with a simple one-skip manoeuvre to a glide trajectory are presented. The principal parameters considered are entry angle up to 6° and lift-drag ratio from $\frac{1}{4}$ to 5. Two values of entry velocity and wing loading were used. Results were obtained by machine integrations of the motion for a radically symmetric earth and a static ARDC atmosphere.—(1.6.2×25.2).

An approximate method for calculating surface pressures on curved profile blunt plates in hypersonic flow. M. O. Creager. N.A.S.A. T.N. D-71. Sept. 1959.
The method of calculation developed utilises a combination of viscous and inviscid hypersonic parameters. The surface pressures predicted by this method are compared to surface pressures measured over a range of Mach numbers from 4 to 13·3 for elliptic and circular leading edges, obtained in air and helium.—(1.6.1×1.2.3.1).

Experimental pressure distributions over blunt two- and three-dimensional bodies having similar cross sections at a Mach number of 4·95. J. D. Julius. N.A.S.A. T.N. D-157. Sept. 1959.
The measurements of pressure distributions were made at Reynolds numbers per foot ranging from 15×10^6 to 75×10^6 for bodies with flat, hemispherical, and oval leading edges. The results were compared with modified Newtonian theory with and without considerations of the centrifugal forces present in the flow field.—(1.6.1×1.2.3).

PERFORMANCE *see also* HELICOPTER AERODYNAMICS

Combined operations with and without afterburning for minimum fuel consumption in level flight. A. Miele and C. R. Cavoti. N.A.S.A. T.N. D-151. Sept. 1959.
Problems of minimum fuel consumption are considered and the possibilities arising from combined operations with and without afterburning explored. The simple case of level flight is investigated and the optimising condition determined. Several numerical examples are included illustrating the general theory and supplying a tangible proof of the minimal character of the solution.—(1.7×27.1).

Minimal maneuvers of high-performance aircraft in a vertical plane. A. Miele. N.A.S.A. T.N. D-155. Sept. 1959.
A general theory is presented for analysing minimal manoeuvres of high-performance aircraft in a vertical plane where the earth is assumed flat and the gravitational field uniform. The indirect methods of the calculus of variations are used and the variational problem formulated as a problem of Bolza type. Problems of either the Lagrange type or the Meyer type are studied as particular cases.—(1.7×27.1).

STABILITY AND CONTROL *see also* WINGS AND AEROFOILS
FLIGHT TESTING
THERMODYNAMICS

Effect of nose length, fuselage length, and nose fineness ratio on the longitudinal aerodynamic characteristics of two complete models at high subsonic speeds. K. W. Goodson. N.A.S.A. Memo 10-10-58L. TIL 6039. *Oct.* 1958.
The results of an investigation made on a model with a swept wing and low tail and a model with a highly tapered wing of moderate sweep and a T-tail are presented.—(1.8.2.2×1.10.2.2).

Experimental wind-tunnel investigation of the transonic damping-in-pitch characteristics of two wing-body combinations. H. F. Emerson and R. C. Robinson. N.A.S.A. Memo 11-30-58A. TIL 6102. *Dec.* 1958.
One model had a straight, tapered wing of aspect ratio 3 and the second model had a triangular wing of aspect ratio 2. The Mach number range was from 0·60 to 1·18 and the Reynolds number varied from 2·3 million to 5·5 million. The results were obtained by a forced-oscillation technique in which an electro-

hydraulic servo valve was used to power the drive system.—(1.8.2.2×1.12.1.1).

A flight investigation of the low-speed handling qualities of a tailless delta-wing fighter airplane. M. D. White and R. C. Innis. N.A.S.A. Memo 4-15-59*A. TIL* 6541. *May* 1959.
Factors that affected the landing-approach characteristics adversely were investigated. Several factors identified with this delta-wing plan form were indicated to contribute to undesirable lateral-directional characteristics. (1.8.1.1×1.3.2).

Airplane and engine responses to abrupt throttle steps as determined from flight tests of eight jet-propelled airplanes. M. D. White and B. A. Schlaff. N.A.S.A. T.N. D-34. *Sept.* 1959.
In conjunction with a generalised landing-approach investigation, aeroplane and engine dynamic responses to abrupt throttle movements were determined. The thrust responses of the engines and the corresponding acceleration responses of the aeroplanes are presented. The relationship of these responses to pilots' ratings of aeroplane approach characteristics is indicated.—(1.8.2.1×27.1.1×13.2).

Effects of body and fin deflections on the aerodynamic characteristics in pitch of a 0·065 *scale model of a four-stage rocket configuration at Mach numbers of* 1·41 *and* 1·82. *R. B. Robinson. N.A.S.A. T.N. D*-37. *Sept.* 1959.
The model was composed of four stages with provision for deflecting each stage with respect to the next rearward stage. Cruciform fins were mounted on all but the fourth stage to provide longitudinal stability and lateral stability and control.—(1.8.2.2).

Wind-tunnel investigation of the aerodynamic characteristics of a model representative of a supersonic fighter-class airplane with an external-flow jet-augmented flap in low-speed flight. W. A. Newsom. N.A.S.A. T.N. D-50. *Sept.* 1959.
The model used in the investigation had an unswept wing of aspect ratio 3·0 equipped with a full-span double slotted flap. An engine nacelle was strut mounted beneath each wing with the jet diverted upward and outward toward the slot of the double slotted flap. Compressed air was used to represent the exhaust of these pod-mounted engines. The investigation was made for three different wing positions and two different horizontal-tail positions for each wing position and included measurements of both longitudinal and lateral stability characteristics.—(1.8.0.2×1.3.4).

Full-scale wind-tunnel investigation of the effects of a target-type thrust reverser on the low-speed aerodynamic characteristics of a single-engine jet airplane. W. H. Tolhurst et al. *N.A.S.A. T.N. D*-72. *Sept.* 1959.
The static stability and control characteristics are presented in the form of three-component force data obtained at Reynolds numbers ranging from 5·8 to $10{\cdot}1\times10^6$. Vector-type plots describe flow angularity and dynamic pressure ratio in probable horizontal tail locations. Data are presented showing effects of thrust reversal on skin temperatures on the fuselage and horizontal tail and on buffeting of the horizontal tail.—(1.8.2.2×27.1×1.3.4).

An analysis of pressure studies and experimental and theoretical downwash and sidewash behind five pointed-tip wings at supersonic speeds. W. B. Boatright. N.A.C.A. Report 1380. 1958.
Three triangular wings of 50°, 63°, and 72° leading edge sweep angle were surveyed at free stream Mach numbers of 1·62 and 2·41. Also surveys were conducted behind the 50° triangular wing reversed, and a straight, 0-taper-ratio wing at Mach number 1·62.—(1.8.2.2×1.10.0.2).

Methods fo measurement of aircraft dynamic stability derivatives. K. Orlik-Ruckemann. N.R.C. Report LR-254. *July* 1959.
The numerous methods available for determination of dynamic stability derivatives of aircraft are presented and grouped according to a convenient classification system. Both free flight and wind tunnel methods are considered. The basic aspects of each method are described in the text and illustrated by a schematic drawing. Detailed information can be obtained from a rather extensive bibliography, arranged according to the same classification system.—(1.8.0.2×1.12.1×1.12.2×13.1.2).

THERMO-AERODYNAMICS *see also* BOUNDARY LAYER
THERMODYNAMICS
FLIGHT TESTING

The influence of aerodynamic heating on the flexural rigidity of a thin wing. E. H. Mansfield. R. & M. 3115. 1959.
The loss of flexural rigidity of a thin wing due to the presence of middle-surface stresses resulting from aerodynamic heating is considered. The spanwise properties of the wing are assumed constant but the wing section is arbitrary. The loss of flexural rigidity is comparable with the corresponding loss of torsional rigidity.—(1.9×33.2.3.1).

An approximate analysis of unsteady vaporization near the stagnation point of blunt bodies. L. Roberts. N.A.S.A. T.N. D-41. *Sept.* 1959.
An approximate analysis of the unsteady sublimation of material near the stagnation point of blunt bodies is presented. The case of unsteady sublimation caused by a steady stream of air is treated in detail and a method is indicated whereby the results may be used in conjunction with experimental values of mass loss to give the effective heat capacity of the material.—(1.9.1).

Shock-tube heat-transfer measurements on inner surface of a cylinder (simulating a flat plate) for stagnation-temperature range 4,100° *to* 8,300°*R. J. J. Jones. N.A.S.A. T.N. D*-54. *Sept.* 1959.
An investigation has been made in a shock tube of the heat transfer rate to the inner surface of a hollow cylinder. The Reynolds number range was from approximately 2×10^5 to 2×10^7. The Mach number range was from about 1·8 to 2·4.—(1.9.1×1.2.3×1.1.3.4×1.12.1).

Turbulent heat-transfer coefficients in the vicinity of surface protuberances. R. J. Wisniewski. N.A.S.A. Memo 10-1-58*E. TIL* 6037. *Oct.* 1958.—(1.9.1).

Le transfert de chaleur par rayonnement. (Rayonnement de la couche de choc et mesure des facteurs d'emission des métaux.) H. de L'Estoile et L. Rosenthal. AGARD Report 211. *Oct.* 1958.
In the first part the author evaluates the radiant heat transfer from the shock layer when the ogives of ballistic missiles re-enter the atmosphere and compares it with that caused by convection at the stagnation point and with the flow radiated by the wall. Numerical results are presented as a basis for general conclusions on the relative extent of the radiant heat transfer from the shock layer and on the choice of value for the emission factor of the surface. The second part discusses the simple and economical method used at the Aeronautical Establishment in Toulouse to measure the emission factor of the metals. This method consists in measuring the energy radiated in a vacuum by a specimen in a temperature equilibrium.—(1.9.1×34.3.1×21.2).

Measurement of the recovery temperature in the wake of a cylinder and of a wedge at Mach numbers between 0·5 *and* 3. *H. Thomann. F.F.A. Report* 84. 1959.—(1.9.1).

WINGS AND AEROFOILS *see also* BOUNDARY LAYER
COMPRESSIBLE FLOW
CONTROLS
LOADS
STABILITY AND CONTROL
TESTING AND INSTRUMENTS

A family of camber lines for subsonic applications (a modified form of the N.A.C.A. family with uniform loading over the forward part and linear loading over the rear part). H. B. Squire. C.P. 457. 1959.—(1.10.1.1).

Transonic flow over two-dimensional round-nosed aerofoils. D. G. Randall. C.P. 456. 1959.
A technique developed by Spreiter and Alksne for determining the pressure distribution over a two-dimensional sharp-nosed aerofoil moving at a speed in the transonic range is extended to the case of a round-nosed aerofoil. If there are no shocks before the trailing edge, Sinnott's method can be used for calculating the pressure distribution over the rear part of the wing. The method is applicable to a round-nosed aerofoil at incidence.—(1.10.1.1×1.2.2.1).

Measured and theoretical flow fields behind a rectangular and a triangular wing up to high angles of attack at a Mach number of 2·46. *F. J. Centolanzi. N.A.S.A. T.N. D*-92. *Sept.* 1959.
Measurements were made behind wings of aspect ratio 2·0 up to 30° angle of attack. The downwash, Mach number, and dynamic pressure in the wakes of both wings are compared with the predictions of shock expansion theory. In the regions where shock

expansion theory is not applicable, the downwash and sidewash are compared with the predictions of vortex theory and linearised theory.—(1.10.2.2×1.8.2.2×1.6.1).

Full-scale wind-tunnel tests of a low-aspect-ratio, straight-wing airplane with blowing boundary-layer control on leading- and trailing-edge flaps. M. W. Kelly et al. *N.A.S.A. T.N. D-135. Sept.* 1959.
Five-component force data are presented showing the effects of applying boundary layer control to the leading and trailing edge flaps of a fighter aeroplane. Also presented are data defining the air flow requirements of the boundary layer control system.—(1.10.2.2×1.3.4×1.3.7×1.1.6.1).

Approximate method for determining the potential flow about an arbitrary aerofoil section in a two-dimensional finite stream with particular reference to large stream deflections. D. G. Gould. N.R.C. Report LR-260. Aug. 1959.
The flow about and on the surface of an aerofoil section in a finite stream and that about and on the surface of the same aerofoil section in an infinite symmetrical cascade are compared.—(1.10.1.1×1.4.1×1.4.1).

Helicopter Aerodynamics

Longitudinal stability and control of the single-rotor helicopter. A. R. S. Bramwell. R. & M. 3104. 1959.
The equations of motion of the helicopter are presented and reduced to non-dimensional form. The force and moment derivatives for the single-rotor helicopter (including tailplane if required) are given as simple formulae or in the form of charts. Comparisons are made with wind tunnel and flight tests where possible and agreement is generally quite good. In the development of the theory, static and manoeuvre stabilities are introduced in a manner analogous to fixed-wing aircraft practice.—(1.11.2).

Helicopter behaviour in the vortex-ring conditions. W. Stewart. R. & M. 3117. 1959.
Flight experience in the vortex-ring conditions with the Sikorsky R-4B, R-6 and S-51, Bell 47 and Bristol 171 helicopters are described.—(1.11.2).

An evaluation of linearized vortex theory as applied to single and multiple rotors hovering in and out of ground effect. H. H. Heyson. N.A.S.A. T.N. D-43. Sept. 1959.
Re-examination of the assumptions of the simple theory indicates reasons for the failure to predict the mutual interference of a two-rotor helicopter model while hovering in ground effect. Correlation of the theoretical results with available flow data indicates those portions of the flow field in which the theory yields reasonable qualitative results.—(1.11.3×29.9×1.4.3).

Comparison of calculated and measured stall boundaries of a helicopter rotor at advance ratios from 0·3 to 0·4. J. L. McCloud and G. B. McCullough. N.A.S.A. T.N. D-73. Sept. 1959.—(1.11.3).

A note on the calculation of helicopter performance at high tip-speed ratios. A. Gessow. N.A.S.A. T.N. D-97. Sept. 1959.
A helicopter performance procedure that accounts for the exact orientation and magnitude of the rotor resultant-force vector is described and illustrated. The procedure utilises existing rotor performance charts and is applicable to operation at high tip speed ratios.—(1.11.3×1.7).

Experimental investigation of the pressure fluctuations on a flat plate and a cylinder in the slipstream of a hovering rotor. J. W. McKee. N.A.S.A. T.N. D-112. Sept. 1959.
Surface pressures were measured for a 12 in. square plate and a 12 in. diameter cylinder for a range of positions in a slipstream generated by a 6 ft. diameter rotor.—(1.11.1×29.9).

Methods for obtaining desired helicopter stability characteristics and procedures for stability predictions. F. B. Gustafson and R. J. Tapscott. N.A.C.A. Report 1350. 1958.
Part I summarises the methods available to the helicopter designer for obtaining desired stability characteristics by modifications to the airframe design. The discussion is based on modifications made during establishment of flying-qualities criteria and includes sample results of theoretical studies of additional methods. In part II some of the methods of predicting rotor stability derivatives have been reviewed and the methods by which the derivatives are used to estimate stability characteristics are summarised.—(1.11.2).

Testing and Instruments *see also* Stability and Control, Thermo-Aerodynamics, Propellers

Experimental study of surface flow and part-span vortex layers on a cropped arrowhead wing. H. C. Garner and D. W. Bryer. R. & M. 3107. 1959.—(1.12.1.1×1.10.2.2×1.1.4.1).

Experimental operating performance of a single-stage annular air ejector. R. R. Howell. N.A.S.A. T.N. D-23. Oct. 1959.
The operating characteristics of a single-stage annular air ejector were established experimentally for a range of pressures and weight flows which allows the ejector to be used as a pump on the discharge end of a hypersonic blowdown wind tunnel. Limited data on the starting characteristics of open and closed hypersonic test sections are presented. Some effects of bluff-body size on the flow in an open hypersonic test section are presented.—(1.12.1.3×1.5.1.4).

Maquettes et equipements de mesure pour la determination en soufflerie des forces aerodynamiques instationnaires. R. Dat. AGARD Report 220. *Oct.* 1958. (*In French.*)
Some of the methods which seem particularly suitable for wind tunnel measurements of unsteady aerodynamic forces are examined. Some aspects of the question of models and their mounting are discussed and examples are given of some of the measuring and excitation apparatus used at the O.N.E.R.A.—(1.12.1×1.6.3).

Development of the spark-heated, hypervelocity, blowdown tunnel-hotshot. R. W. Perry and W. N. Macdermott. AGARD Report 233. *June* 1958.
The history, description, performance, and typical test data for the first Hotshot type wind tunnel are presented. In addition, a brief account of advanced developments based on the electric-discharge method of heating gases is given.—(1.12.1.3).

AEROELASTICITY

See Instruments and Equipment

DESIGN AND CONSTRUCTION

See also Flight Testing

Analytical and experimental determination of the coupled natural frequencies and mode shapes of a dynamic model of a single-rotor helicopter. M. A. Silveira and G. W. Brooks. N.A.S.A. Memo 11-5-58*L. TIL* 6143. *Dec.* 1958.
An analytical procedure for the calculation of the coupled natural frequencies and mode shapes in the longitudinal plane of symmetry is presented. The frequencies and mode shapes are then calculated for a dynamic-model helicopter and compared with measured values.—(4.4×33.1.2).

AIRCRAFT OPERATION

See also Fuels and Lubricants, Propellers

Effects of water-landing impact on an orbital capsule from the standpoint of occupant protection. H. G. Hatch. N.A.S.A. T.N. D-39. Sept. 1959.
The full-size model used to obtain the data was a conical-shaped capsule with a segment of a sphere as the bottom. Literature on human tolerance to accelerations indicates that a rate of 1,500 g/sec. to a level of 40*g* is about maximum for survival without injury. For the velocity expected with a parachute (30 ft./sec.), the distance required to stop within the tolerable acceleration limits is 8·54 in. This could be obtained by supporting the occupant with a crushable structure or a mechanical spring system.—(5.3×33.1).

Ground measurements of the shock-wave noise from airplanes in level flight at Mach numbers to 1·4 and at altitudes to 45,000 ft. D. J. Maglieri et al. *N.A.S.A. T.N. D-48. Sept.* 1959.
Time histories of noise pressures near ground level were measured at several locations during high-altitude flights of fighter-type aeroplanes over fairly flat, partly wooded terrain.—(5.6×24×1.2.3.2).

An investigation to determine conditions under which downwash from VTOL aircraft will start surface erosion from various types of terrain. R. E. Kuhn. N.A.S.A. T.N. D-56. Sept. 1959.—(5×6×29.9×11).

Field experiments on treatment of fluorine spills with water or soda ash. R. J. Rollbuhler et al. *N.A.S.A. T.N. D-63. Sept.* 1959.
Investigation was made of the use of water or soda ash as a deluge agent to reduce contamination from accidental fluorine spills. Tests with both gaseous and liquid fluorine were made in a structure typical of a building in which fluorine might be used.—(5.3×27.3×14×34.1.1).

Dispersion of jettisoned JP-4 jet fuel by atmospheric turbulence, evaporation, and varying rates of fall of fuel droplets. H. H. Lowell. N.A.S.A. T.N. D-84. Oct. 1959.
Ratios of jettisoned JP-4 fuel (in droplet form) to air were calculated for four weather situations: a warm, windy day; a warm, quiet day; a cold, windy day; and a cold, quiet day.—(5.3×34.1.1).

AIRPORTS

Measurements and power spectra of runway roughness of an airport (Airport 7). AGARD Res. Memo 7. Sept. 1959.—(6.1).

Measurements and power spectra of runway roughness of an airport (Airport 8). AGARD Res. Memo 8. Sept. 1959.—(6.1).

EXTRA-ATMOSPHERIC TECHNOLOGY

Gravity torque on an orbiting vehicle. B. F. Doolin. N.A.S.A. T.N. D-70. Sept. 1959.
The equations of motion of an artificial satellite of the earth are calculated with a choice of parameters dictated by stability study considerations. For an example, the equations are reduced to the case of a symmetrical body in a circular orbit.—(8×22).

Three-dimensional orbits of earth satellites, including effects of earth oblateness and atmospheric rotation. J. N. Nielsen et al. *N.A.S.A. Memo 12-4-58A. TIL 6141. Dec.* 1958.
Complete trajectories of earth satellites have been studied from outer space to the ground using automtic computation. Equations of motion based on an "instantaneous ellipse" method were found suitable for automatic computation up to the terminal phase of the trajectory. For the terminal phase equations of motion using time as an independent variable were found more suitable. Several sample calculations were performed to study the effect of the earth's oblateness and the atmosphere's rotation on the motion and the point of impact.—(8×25.2).

Meteor trains. R. F. Hughes. Smith. Cont. Astro. Vol. 3, No. 8. 1959.
Data are presented on the heights, durations and intensities of 48 meteor trains.—(8.1).

AVIATION MEDICINE

Aeronautical preventive medicine. Symposium held 26 November 1957. *Washington, D.C., U.S. AGARDograph 36. Nov.* 1957.
Six papers, emphasising the importance of industrial medicine in the air operational system.—(9).

ELECTRONICS

See AIRCRAFT OPERATION
MATHEMATICS

FLIGHT TESTING

See also AERODYNAMICS—STABILITY AND CONTROL

Flight investigation of a centrally located rigid force control stick used with electronic control systems in a fighter airplane. W. R. Russell and W. L. Alford. N.A.S.A. T.N. D-102. Sept. 1959.
The force stick was similar in size and location to a conventional control stick and was used with both a rate automatic control system and an irreversible electronic power control system. Pilots' opinions of the force stick are included.—(13.2×1.8×4.2.1).

An assessment of the probable causes of variation of the speed-correction coefficient of aircraft thermometers. D. D. Clark. R. & M. 3127. 1959.—(13×24×1.1.2×1.9.1).

FUELS AND LUBRICANTS

See also AIRCRAFT OPERATION
POWER PLANTS

Free fall and evaporation of JP-4 jet fuel droplets in a quiet atmosphere. H. H. Lowell. N.A.S.A. T.N. D-33. Sept. 1959.
A theoretical investigation was made in which the actual fuel was simulated by a mixture of 10 hydrocarbon fractions having different boiling points. Mass loss rates were large at temperatures above 0°C, particularly for droplets having diameters less than 1250 microns, but even for larger droplets mass losses substantially altered the altitude-time fall histories and would substantially decrease expected fuel concentrations at ground level.—(14×34.1.1×5.3).

Analytical comparison of hydrazine with primary propellants as the turbine drive fluid for hydrogen-fluorine and hydrogen-oxygen altitude stage rockets. W. T. Wintucky. N.A.S.A. T.N. D-78. Oct. 1959.
Primary propellants, hydrogen-fluorine and hydrogen-oxygen, were compared with a high-energy monopropellant, hydrazine, as the turbine drive fluid for two high-energy-rocket altitude stages of 20,000 pounds nominal thrust. A range of rocket velocity increments for both vertical and horizontal flight was covered.—(14×27.1).

The thermal stability of unsymmetrical dimethylhydrazine. A. E. Spakowski. N.A.S.A. 12-13-58*E. TIL* 6142. *Dec.* 1958.
The self-ignition and spontaneous decomposition temperatures of unsymmetrical dimethylhydrazine were determined at atmospheric pressure to be 454° and 740°F, respectively. The larger value (740°F) was obtained in an inert atmosphere of nitrogen and represented the minimum temperature that would cause a rapid exothermic reaction.—(14×34.1.1.1×27.3).

INSTRUMENTS AND EQUIPMENT

Investigations into the use of an electrical resistance analogue for the solution of certain oscillatory-flow problems. P. J. Palmer et al. *R. & M.* 3121. 1959.
The use of an electrical resistance analogue, for solving the problem of a thin two-dimensional wing oscillating in an incompressible ideal fluid, is considered; wings with and without flaps are investigated. The particulars of the design and construction of a special graded analogue are given. Experimental results are obtained for flat plates, with and without flaps, oscillating harmonically with small amplitudes in a steady stream. These experimental results are in close agreement with theory.—(18×2×1.6.3).

MATERIALS

See also AERODYNAMICS—THERMO-AERODYNAMICS
FATIGUE
STRUCTURES—THEORY AND ANALYSIS

Some results on the crazing of Perspex including the effect of humidity. B. A. Blythe and W. W. Wright. C.P. 454. 1959.
The effect of humidity on the stress crazing of Perspex by four crazing agents has been investigated. A quantitative value for the change in threshold crazing stress with change in relative humidity has been derived. A table of threshold crazing stresses for Perspex with a range of liquids has been compiled.—(21.3.3).

Ductile ceramics. I—Factors affecting the plasticity of sodium chloride lithium fluoride, and magnesium oxide single crystals. C. A. Stearns et al. *N.A.S.A. T.N. D-75. Oct.* 1959.
A study was made of the influence on the behaviour in bending and compression of treatments such as water-polishing, varying cleavage rate, annealing, quenching, X-irradiation, surface coating, and ageing. Etchpit studies were made of the modifications in dislocation concentration and distribution.—(21.3.1).

Ductile ceramics. II—Introductory study of ductility in polycrystalline sodium chloride and magnesium oxide. C. E. May et al. *N.A.S.A. T.N. D-76. Oct.* 1959.
Polycrystalline sodium chloride was made to exhibit ductility in bend tests by a vapour deposition of silver on each crystallite in the specimen. Other treatments, such as a stearic acid coating, were not as successful.—(21.3.1).

High-temperature tensile properties of wrought sintered tungsten. P. F. Sikora and R. W. Hall. N.A.S.A. T.N. D-79. Sept. 1959.
Tensile tests at temperatures from 2500° to 4400°F were conducted on specimens fabricated from commercially pure tungsten. Material from five different producers was evaluated. Ultimate tensile strengths and fracture ductility data are reported.—(21.2).

Thermal-stress fatigue cracking of turbine buckets operated at 1700°F in a turbojet engine with frequent starts and stops. R. A. Signorelli et al. *N.A.S.A. T.N. D-125. Oct.* 1959.
An investigation conducted to determine the effects of advanced-temperature operation on the thermal-stress fatigue resistance of nickel-base alloys SEL-1, B and B, Inconel 713, cast Udimet 500, and wrought Udimet 500 indicated that all of the materials tested developed thermal-stress fatigue cracks after short operating times in a J47 engine.—(21.2×31.2.2.7.1.8×27.1).

Technique non destructive pour les observations, en particulier de nature métallographique, sur les surfaces métalliques. P. A. Jacquet. O.N.E.R.A. N.T. 54. 1959. (*In French.*)—(21.1×21.6).

MATHEMATICS

See also EXTRA-ATMOSPHERIC TECHNOLOGY
STRUCTURES—THEORY AND ANALYSIS

General-purpose subroutines for the IBM 650 magnetic drum data-processing machine with attachments. V. N. Huff et al. *N.A.S.A. T.N. D-68. Oct.* 1959.
A set of routines has been designed for use with the IBM 650 Magnetic Drum Data-Processing Machine. These routines are intended for general-purpose use on engineering calculations.—(22).

The determination of the natural modes of a physical system. J. A. Phillips. A.R.L. Report I. 21. *June* 1959.
The poles of the transfer function of a system may be determined by noting the change in transient response when one of the poles is cancelled by a zero having known co-ordinates. An apparatus for carrying out this operation has been constructed and tested on simple transfer functions.—(22.1×11).

METEOROLOGY

See AERODYNAMICS—LOADS
AIRCRAFT OPERATION
FLIGHT TESTING

MISSILES

See AERODYNAMICS—LOADS
EXTRA-ATMOSPHERIC TECHNOLOGY

POWER PLANTS

See also AERODYNAMICS—COMPRESSIBLE FLOW
PERFORMANCE
STABILITY AND CONTROL
AIRCRAFT OPERATION
FUELS AND LUBRICANTS
MATERIALS

Propellant vaporization as a criterion for rocket-engine design; experimental effect of chamber diameter on liquid oxygen-heptane performance. M. F. Heidmann. N.A.S.A. T.N. D-65. Sept. 1959.
Characteristic velocity was evaluated for various chamber diameters and lengths in a nominal 200-pound-thrust combustor. A heptane spray produced by two impinging jets reacting with highly atomised oxygen was used. A comparison of performance variations with combustor length was made.—(27.3×14).

Analysis of effects of rocket-engine design parameters on regenerative-cooling capabilities of several propellants. A. N. Curren et al. *N.A.S.A. T.N. D-66. Sept.* 1959.
An analytical study of the regenerative-cooling requirements of rocket engines using high-energy liquid propellants was conducted. Each of seven major engine design parameters was varied independently to evaluate its significance in cooling considerations.—(27.3×34.3.4).

A general method for automatic computation of equilibrium compositions and theoretical rocket performance of propellants. S. Gordon et al. *N.A.S.A. T.N. D-132. Oct.* 1959.
A general computer programme for chemical equilibrium and rocket performance calculations was written for the IBM 650 computer. The programme can carry out combustion and isentropic-expansion calculations on a chemical system that may include as many as 10 different chemical elements, 30 reaction products, and 25 pressure ratios. It calculates composition, temperature, pressure, specific impulse, specific impulse in vacuum, characteristic velocity, thrust coefficient, area ratio, molecular weight, Mach number, specific heat, isentropic exponent, enthalpy, entropy, and several thermodynamic first derivatives.—(27.3×14×34.1.1).

Structural design and preliminary evaluation of a lightweight, brazed, air-cooled turbine rotor assembly. A. J. Meyer and W. C. Morgan. N.A.S.A. Memo 10-5-58*E. TIL* 6104. *Dec.* 1958.
A light-weight air-cooled turbine rotor assembly intended for short-life expendable missile application and which results in a 50 per cent weight reduction over a conventional turbine was devised and stress analysed. Two rotor blade configurations with simulated full wheel attachment were tested in a full-scale engine.—(27.1×33.2.4.1.10).

PROPELLERS

See also AERODYNAMICS—BOUNDARY LAYER
HELICOPTER AERODYNAMICS
AIRCRAFT OPERATION

Large-scale wind-tunnel tests of an airplane model with an unswept, aspect-ratio-10 wing, four propellers, and blowing flaps. J. A. Weiberg and V. R. Page. N.A.S.A. T.N. D-25. Sept. 1959.
The longitudinal aerodynamic characteristics were determined and compared with data previously presented for the model with two propellers.—(29.9×1.34×1.1.6.1).

Measurements of free-space oscillating pressures near propellers at flight Mach numbers to 0·72. M. C. Kurbjun and A. W. Vogeley. N.A.C.A. Report 1377. 1958.
Limited measurements have been made of the free-space oscillatory pressures near the tips of propellers at flight Mach numbers up to 0·72. Measurements were made at a single radial station and at three axial positions (ahead of, in the plane of, and behind the propeller disc).—(29.1×5.6×1.12.2).

REFERENCE LITERATURE

*List of reports on the fatigue of materials, components and structures published by The Aeronautical Research Laboratories. J. Y. Mann. A.R.L. T.M. SM.*82. *May* 1959.—(30.1×31.2.2×31.2.3).

FATIGUE

See also MATERIALS
REFERENCE LITERATURE

The rate of fatigue-crack propagation for two aluminum alloys under completely reversed loading. Walter Illg and Arthur J. McEvily, Jr. N.A.S.A. T.N. D-52. Oct. 1959.
A series of crack propagation tests of sheet specimens has been conducted under completely reversed loading at various stress levels up to 30 ksi. Differences between effects of the compression and tension parts of the cycles are discussed. Semi-empirical equations are developed which permit calculation of crack growth. Results are compared with those from similar tests made at a minimum stress of 1 ksi. In both types of loading, the governing parameter was found to be related to the local stress at the crack tip.—(31.2.2.3.2.1.6×21.2.2×33.1.2).

STRUCTURES

LOADS *see* DESIGN AND CONSTRUCTION
AIRCRAFT OPERATION
FATIGUE

THEORY AND ANALYSIS
See also AERODYNAMICS—THERMO-AERODYNAMICS
POWER PLANTS
THERMODYNAMICS

Theoretical analysis of the creep collapse of columns. F. R. Schlecte. N.A.S.A. T.N. D-95. Sept. 1959.
A creep variational principle is applied to analyse idealised H-section and solid rectangular-section columns. For the rectangular-section columns, in one case the stress distribution through the thickness is assumed to be linear, and in another case the stress distribution is permitted to be non-linear. Charts are given for the critical lifetime parameters based on these various theories. Comparisons are made between the theories for the rectangular-section columns and previously published test data.—(33.2.4.2.9).

XUM

Handbook of structural stability. Part VII—strength of thin-wing construction. G. Gerard and H. Becker. N.A.S.A. T.N. D-162. Sept. 1959.
The stability of various forms of stiffened and sandwich plates which have been considered for the compression covers of thin wings is presented in terms of orthotropic plate theory. Design charts are given and methods of evaluating the plate elastic constants are reviewed. Buckling and failure of multiweb, multipost and multipost-stiffened forms of beam construction are considered in terms of available theoretical and experimental results.—(33.2.3.2×33.2.4.6×33.2.4.14).

Handbook of structural stability. Supplement to Part III—Buckling of curved plates and shells. G. Gerard. N.A.S.A. T.N. D-163. Sept. 1959.
Recent theoretical and experimental results on buckling of curved shells are reviewed and interpreted in terms of analyses presented in the "Handbook of Structural Stability. Part III—Buckling of Curved Plates and Shells" (N.A.C.A. T.N. 3783, 1957). A considerable mass of recent experimental data on buckling of cylinders under pressure is correlated with existing theories.—(33.2.4.8×33.2.4.3).

Buckling of simply supported rectangular sandwich panels subjected to edgewise bending. W. E. Jahnke and E. W. Kuenzi. F.P.L. Report 1868. *March* 1959.
The buckling of rectangular flat sandwich panels when subjected to edgewise bending was investigated experimentally. Panels of two sizes were tested; each had thin aluminium facings bonded to an aluminium honeycomb core.—(33.2.4.14.2×21.2.3).

Design curves for the buckling of sandwich cylinders of finite length under uniform external lateral pressure. C B. Norris and J. J. Zahn. F.P.L. Report 1869. *May* 1959.
Curves and formulae for the calculation of the critical external pressure of sandwich cylinders of finite length are given. The facings of the sandwich are equal and isotropic and their individual stiffness is not taken into account. The core is isotropic or orthotropic having natural axes in the axial, tangential, and radial directions of the cylinder. (33.2.4.3.7×33.2.4.14.7).

Effect of tensile and compressive preloading on tensile, compressive, and shear properties of a glass-fabric-base epoxy laminate. K. E. Kimball. F.P.L. Report 1870. *May* 1959.—(33.2.4.14×21.3.6).

Organization of a large computation in aircraft stress analysis. A. L. M. Grzedzielski. N.R.C. Report LR-257. July 1959.
Theoretical and organisational aspects of a large scale numerical stress analysis covering effects of applied loads and uneven temperature are discussed. The underlying stress analytical theory and the required matrix symbolism are explained using the example of a swept multi-spar model box for which experimental data are available. A large scale computation, actually performed during the design of a prototype aircraft, is described.—(33.2×22.1).

General introduction to thermal structures. J. Taylor. AGARD Report 206. *Oct.* 1958.
The basic aerodynamics and materials data for the study of thermal structures are surveyed, and the basic structural theory that has been developed is reviewed. A special discussion is made on the new feature in structural design of combining strains due to temperature and strains due to load. Special emphasis is made on its effect on design requirements.—(33.2.4.0.9).

Theory of structural design. W. S. Hemp. AGARD Report 214. *Oct.* 1958.
The real problem of structural design is the direct design of a structure which will equilibrate the external loads, without failure or undue deformation, under such conditions of temperature as may be appropriate, and which at the same time will have the least possible weight. The classical results and their current application are reviewed. The mathematical theory for the two-dimensional case is developed and a number of special solutions derived.—(33.3).

Fusoliere a sezione non circolare. P. Santini. Mono. Sc. di Aero. No. 5. June 1959. (*In Italian.*)
The problem of the distribution of stresses and displacement in a fuselage structure of non-circular section, with rigid ribs is taken into consideration. The Balance method is used. The complete solution of the problem is given, with some typical results, which provide an idea of the effect of non-circularity.—(33.2.3.3×33.2.4.3).

*On the stress problem of anisotropic wedges. J. P. Benthem and J. v. d. Vooren. NLL-TN S.*537. *Feb.* 1959.
Infinite anisotropic wedges with prescribed loads in their plane along the edges are considered. The differential equation for Airy's stress function is given in terms of oblique co-ordinates. Solutions are also derived for unloaded edges.—(33.2.4.6.8).

*On the diffusion of a load from an edge-stiffener into a wedge-shaped plate. J. P. Benthem and J. v. d. Vooren. NLL-TN S.*541. *July* 1959.
The method has been developed to apply it to more complex cases, such as anisotropic wedges with more than one stiffener. A functional equation for the Mellin transform of the shear flow along the stiffener is obtained. An inverse Mellin transform results in a singular integral equation which must be solved numerically. Applications are given for vertex angles of 135° and 180°.—(33.2.4.6.8).

THERMODYNAMICS

See also AERODYNAMICS—BOUNDARY LAYER
FLUID DYNAMICS
THERMO-AERODYNAMICS
AIRCRAFT OPERATION
FUELS AND LUBRICANTS
POWER PLANTS

Heat-transfer and friction measurements with variable properties for airflow normal to finned and unfinned tube banks. R. G. Ragsdale. N.A.S.A. Memo 10-9-58*E. TIL* 6106. *Dec.* 1958.
Average heat transfer and friction coefficients are reported for heat addition to air flowing normal to staggered banks of electrically heated finned and unfinned tubes for variable property conditions. The data are for Reynolds numbers from 2,000 to 35,000 and surface-to-bulk temperature ratios from 1·07 to 2·36.—(34.3×1.9.1).

Cooling of structures in high speed flight. C. B. Neel. AGARD Report 210. *Oct.* 1958.
Various possible ways of cooling critical areas of structures are discussed. The electrical heat-flow analogue used is described, and a new simplified method is given which appears useful in computing wing leading edge temperature, including the effects of radiation, heat capacity and heat conduction.—(34.3.4×33.2.3.2.9×18.1).